

Master of Science in Computational Mechanics Module Handbook

Universitat Politècnica de Catalunya/CIMNE
University of Wales Swansea
École Centrale de Nantes
Universität Stuttgart

1. WELCOME

Welcome to the Erasmus Mundus Masters in Computational Mechanics. This is an innovative programme supported by the European Commission under the Erasmus Mundus initiative, and designed to promote student mobility within masters programmes.

You will spend your first semester in Barcelona, Spain or Swansea, Wales before moving to Nantes (France), Stuttgart (Germany), Barcelona (Spain) or Swansea (Wales) for your second, third and fourth semesters.

The purpose of this handbook is to explain how the Erasmus Mundus Masters in Computational Mechanics will work, and what you can expect from it. The information is intended to help you find your feet and settle into postgraduate life as quickly as possible. The handbook outlines what you can expect at each stage of your studies, the resources available, the structure and staffing at each institution where you will be studying, and procedures for dealing with any problems you may encounter.

Please read this handbook carefully as it is in your interest to familiarise yourself with the regulations and procedures.

Students who are uncertain about the information in this handbook should ask their course coordinator or contact any of the departmental offices.

We hope you will find your time as a member of the postgraduate community at each institution rewarding and enjoyable

2. DISCLAIMER

The Consortium has made all reasonable efforts to ensure that the information contained within this publication is accurate and up-to-date when published but can accept no responsibility for any errors or omissions.

The Consortium reserves the right to revise, alter or discontinue modules and to amend regulations and procedures at any time, but every effort will be made to notify interested parties.

It should be noted that not every module listed in this handbook may be available every year, and changes may be made to the details of the modules.

3. ERASMUS MUNDUS – THE EUROPEAN PROGRAMME OF ACADEMIC EXCELLENCE AND WORLD-WIDE STUDENT MOBILITY

What is the Erasmus Mundus programme?

The Erasmus Mundus programme is a cooperation and mobility programme in the field of higher education. It aims to enhance quality in European higher education and to promote intercultural understanding through cooperation with third countries.

With a budget of EUR 230 million for the period 2004-2008, the programme is intended to strengthen European cooperation and international links in higher education by supporting high-quality European Masters Courses, by enabling students and visiting scholars from around the world to engage in postgraduate study at European universities, as well as by encouraging the outgoing mobility of European students and scholars towards third countries.

Erasmus Mundus Masters Courses

Erasmus Mundus supports European top-quality courses at Master level in order to promote the EU as a centre of excellence in learning around the world. These are integrated courses of one to two years offered by at least three universities from three different European countries. They involve a study period in at least two of the three universities and lead to the award of a recognised double, multiple or joint degree.

Scholarships for third country students and scholars

In order to encourage graduate students and scholars from all over the world to obtain qualifications and experience in Europe, a scholarship scheme for highly qualified third country nationals is linked to the Erasmus Mundus Masters Courses. Students receive scholarships to follow the Masters Courses, scholars to teach or do research.

For further information on Erasmus Mundus:

<http://europa.eu.int/comm/education/programmes/mundus/>

4. BEING A STUDENT ON THE ERASMUS MUNDUS MASTERS PROGRAMME

Key dates

Dates of Semesters:

Year 1

Semester 1: UPC:

Swansea University: 24 Sept 07 – 31 January 08

Semester 2: UPC:

Swansea University: 1 February 08 -

Stuttgart University:

Ecole Centrale de Nantes:

Year 2

Semesters 3 & 4:

UPC:

Swansea University:

Stuttgart University:

Ecole Centrale de Nantes:

Enrolment

The enrolment process is a means of recording data on students and for institutions to provide important information to students. During the enrolment process students also declare that they will abide by the regulations of the universities concerned.

Students will enroll at their starting institution.

Notification of change of address

The Consortium needs to be informed of any change of address – whether it is a change in term-time or home address. Normally students should inform the Scheme coordinator at whichever institution they are studying. The coordinator will then have the responsibility for informing all other institutions within the Consortium.

Whilst studying in Barcelona please notify change of address to: Ms. Lelia Zielonka, lelia@cimne.upc.edu

Whilst studying in Swansea please notify change of address to the Departmental Coordinator _____ and to the Accommodation Office, tel: 01792 295101, e-mail: accommodation@swansea.ac.uk

(Website: <http://www.swan.ac.uk/accommodation/index.htm>).

Whilst studying in Stuttgart please notify change of address to

Whilst studying in Nantes please notify change of address to

Regulations

By enrolling in this course, students agree to abide by the Academic Regulations and Assessment Regulations included in this handbook. In addition, each university may have its own general or financial regulations that students will need to adhere to. Information on these will be provided when you commence studies in that institution.

Attendance and progress

Students are expected to attend all lectures and examinations scheduled. It is recognised however, that due to illness or exceptional circumstances, this may not be possible in all instances. Students should report absences and reasons for them to the scheme coordinator at whichever institution they are studying. You may be required to present a medical certificate where this is appropriate.

In addition, students are reminded that they should inform the Scheme co-ordinator of any circumstances they feel might adversely affect their performance. Failure to do so will result in you not having legitimate grounds for appeal of assessment decisions. The local coordinator will be responsible for informing the appropriate Examining Board.

General conduct and behaviour

Students shall conduct themselves in an orderly manner. Please note that:

If you willfully damage University property you must pay for its repair and may be subject to disciplinary action.

If you attempt to obstruct teaching, study, research or the administration of any Institution within the Consortium you will be liable to disciplinary action.

Unauthorized absence from any part of your course without proper cause will render you liable to disciplinary action.

You are under an obligation to inform the Consortium of any criminal conviction prior to and during your period as a student.

Each institution operates its own disciplinary procedures. Information on these will be provided to students during their induction at that institution.

Complaints

The Consortium is committed to ensuring a high quality educational experience for its students, supported by appropriate academic, administrative and welfare support services and facilities within each of its institutions. In order to help us to help you and improve our delivery and support, you are under an obligation to raise and resolve any issues that you may be dissatisfied about at the institution in which you are studying as soon as they arise. Most issues can be resolved quickly. If problems persist issues can be raised with the course coordinator or in Swansea at Student/Staff committees. In exceptional circumstances students might feel the need to pursue a complaint through the formal complaints procedures. Details of these procedures will be available in the respective institutions. It would be envisaged that formal complaints will have been resolved before moving on to the next institution within the Consortium.

Should a student be unable to resolve a complaint to their satisfaction within the institution concerned, he/she may approach the Board of Studies of the Consortium. An independent member of the Board will be asked to conduct an investigation into the complaint.

Extensions to deadlines

Please speak to your personal tutor/advisor or scheme coordinator at whichever institution you are currently studying for advice if you believe you have extenuating circumstances which might be affecting your studies. Seek advice on whether to apply for an extension to any course assessment deadline or to your overall deadline.

Extending the deadline for individual assessments

The assessment deadlines for each module will be given to you by the module tutor and or the module handbook at the outset of the semester. There should be no excuse therefore for missing these deadlines. In exceptional circumstances due to ill health or exceptional personal reasons you may find that you are unable to meet a deadline. In this case you should contact the relevant professor as soon as you become aware that there is an issue and before the submission date in question. You should state your case in writing and provide appropriate documentary evidence to support your request.

Transcripts and diploma supplement

Students will be issued with an academic transcript and a Diploma Supplement at the end of their studies (free of charge). The diploma supplement is a document, which aims to facilitate academic and professional recognition of qualifications across Europe. It provides a description of the nature, level, context, content and status of the

studies that were pursued and successfully completed by the individual named.

Graduation

The degree shall be conferred upon successful candidates at an awards ceremony, date and location to be confirmed. The degree certificate(s) to be issued shall include reference to the collaborative nature of the degree and shall include the name of each institution involved in the teaching. Exit qualifications shall not normally be awarded to candidates at a ceremony, but such awards shall be conferred upon candidates administratively.

The Erasmus Mundus Alumni Association

In the spring of 2006 the European Commission and student representatives from all Erasmus Mundus programs launched the Erasmus Mundus Alumni Association.

The association is free to join for Erasmus Mundus students. You can register at the webpage www.erasmusmundus-alumni.edu and get instant access to an online student forum, a newsletter and a database of students and former students.

5. ORGANIZERS

An international Consortium of four leading European Educational and Research Institutions in cooperation with the International Center for Numerical Methods in Engineering (CIMNE).

All institutions of the consortium have a long standing tradition in the field Computational Mechanics, with the highest standards both in research and teaching.

Universitat Politècnica de Catalunya, UPC (Barcelona, Spain)

www.upc.edu

University of Wales Swansea, UWS (UK)

www2.swan.ac.uk

Ecole Centrale Nantes, ECN (France)

www.ec-nantes.fr

Universität Stuttgart, US (Germany)

www.uni-stuttgart.de

CIMNE is an autonomous international research organization specialized in the development and application of numerical methods in engineering.

www.cimne.com

Practical information about the organizing institutions is included in section 12, at the end of this handbook

6. PRESENTATION

The Master of Science in Computational Mechanics is designed for students who wish to develop their knowledge and competency in the field of computational mechanics with applications in solids, fluids and interdisciplinary fields. The goal is to provide the students with the skills for the modelling, formulation, analysis and implementation of simulation tools for advanced engineering problems, as well as skills for understanding these approaches in the broader context of engineering science. Students will benefit from a leading group of faculty and an exciting international environment. Students may take the Master's as a professional terminal degree, or in preparation for a Ph.D. degree.

The programme lasts two academic courses (120 ECTS) and includes the Master Thesis as well as Practical Training in an industrial or applied research environment. The first term is aimed at providing a solid background on mechanics and numerical methods. It consists of a set of core modules (20 ECTS) complemented by elective modules (10 ECTS) and a Research Planning module. These core modules are taught jointly UPC and UWS. Students can select to follow the first term either at UPC or UWS. The second term (30 ECTS) consists of a minor aimed at providing a deeper knowledge in a selected area. The second term must be followed in a 2nd institution different from the selected for the first term. The Master's Thesis is supervised and developed in the 2nd institution during the 3rd and 4th terms. Practical training at industry or an applied research centre will also be provided during these last two terms.

7. ADMISSIONS

Admission requirements

A candidate must hold a Bachelor of Science or Engineering, or an appropriate science degree deemed to be a satisfactory standard for the purpose of postgraduate admission (at least 180 ECTS) and awarded by an institution recognized by one of the members of the consortium. Applications must include a statement of purpose (one/two pages), a CV, complete academic transcripts and three letters of recommendation. A score of at least 6.5 IELTS (or equivalent TOEFL or TOEIC) is required for students from non-English speaking countries.

Application Process (via web) <http://www.cimne.com/cdl>

For further questions please contact the master's Secretariat science@cimne.upc.edu

Tuition Fees

The fees for the duration of the course will be 16 000 € for third-country students and 8 000 € the others. CIMNE will collect fees in four instalments at the start of each term.

Financial Support

A limited number of grants offering total or partial support to cover the course tuition fees are available. Further information will be posted at the Master's web page www.cimne.com/cm-master.

8. MOBILITY AND LANGUAGE POLICY

Students study in two of the Consortium institutions. They meet all together in Barcelona on two occasions. First, at the beginning of the first academic year during an **Induction Weekend** to meet the class, teachers, the different institutions and get all the information related to the Master Program (Student Handbook, virtual centre, etc.). And second at the beginning of the second academic year to present the **Research Project Plan**. They pursue their 1st term in the first institution (UPC / UWS), which is responsible for teaching 35 ECTS. Their 2nd, 3rd and 4th terms (85 ECTS) are conducted in the second institution (obviously, different from that of their 1st term), which is any of the four: UPC / UWS / ECN / US. Mobility of students is restricted to the period between the 1st and 2nd terms.

The choice of institution depends mostly on the student's preferences and also on an even distribution of students among the institutions. Students present their preferences in the admission form. The Board of Studies at its winter meeting decides both if a student is admitted and his/her corresponding mobility. This decision is communicated to the student before the registration period.

All partner institutions have wide-ranging experience with international exchanges and have well-developed logistical systems to coordinate the welcome and assistance of international exchange students. At each partner institution international offices, in cooperation with the local academic host (viz. department, institute, etc.), will coordinate the logistics including housing facilities, visas, social security and other relevant information before arrival.

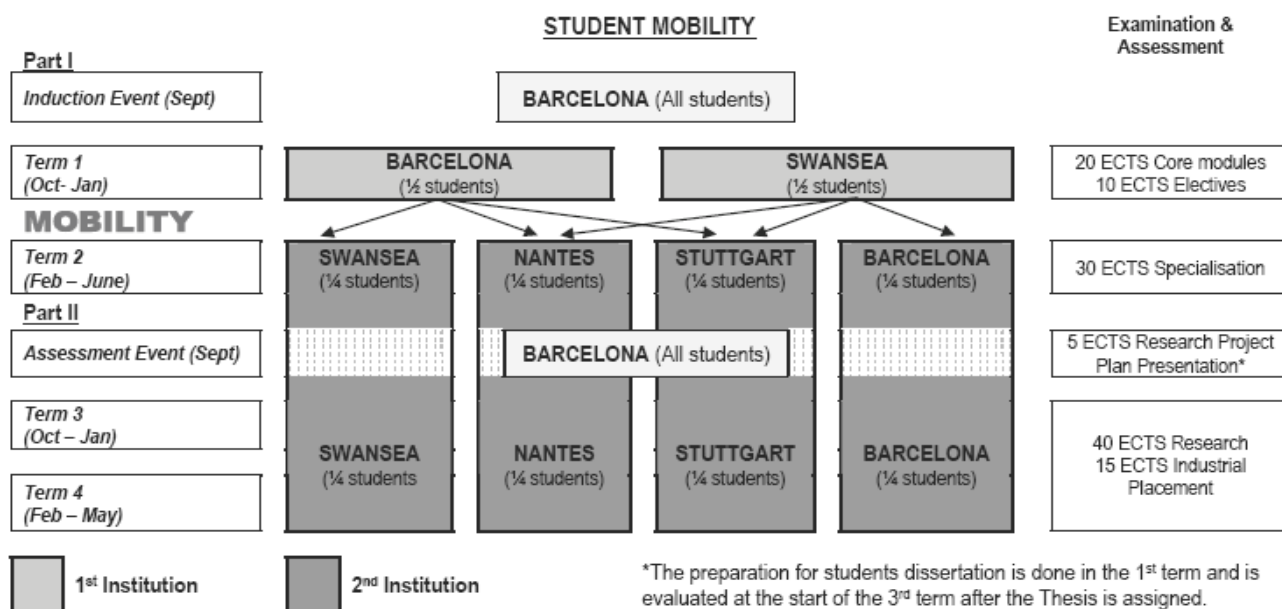
The international offices provide support during the stay, with dedicated staff offering supervision and advice. Upon arrival each student will be assigned a mentor, a native speaker, who will ensure that the student is welcomed and settled into his/her accommodation. Social and cultural integration will be facilitated by ensuring that international students are where possible co-located with native students. Support and advice for specific health treatments is also provided.

The language of instruction and examination is English throughout the Programme. Before being admitted to the course non-native English speaking students must demonstrate high levels in both written and spoken English, with an IELTS minimum score of 6.5 or equivalently internationally accredited qualification. All theses must be written in English and any public defence must also be conducted in English.

All institutions making up the Consortium offer students intensive national language classes in order to assist students with the integration into the respective countries. This includes Catalan in Barcelona and Welsh in Swansea.

9. PROGRESSION AND AWARD REGULATIONS (ASSESSMENT RULES)

1. STRUCTURE OF SCHEME



The scheme consists of two parts- Part I, taught modules (terms 1 and 2), followed by a research dissertation and practical component- Part II (terms 3 and 4).

The first term is taught simultaneously in Barcelona and Swansea. Students study commonly agreed modules, totalling 20 ECTS, which are examined jointly. In addition, students study a further locally chosen and assessed modules, totalling 10 ECTS. Students also receive preparation for their dissertation, in the form of a 5 ECTS credit module, which is assessed at the start of the third term (Part II). Students must accumulate 30 ECTS by passing each module at 50 or above to progress.

The second term is taught at a second designated institution from within the consortium (from a choice of UPC, UWS, US and ECN). Students must accumulate 30 ECTS (at least 15 of which should be in one specialist subject area) during the second term to proceed to Part II (the third and fourth term) at the same institution.

Part II (the third and fourth terms) consists of an assessment of the students' research project plans (5 ECTS), research thesis (40 ECTS) and an Industrial Project (15 ECTS).

Progression Boards will be held at the end of the first and second term to determine students' progression to the subsequent term(s).

2. GENERAL PRINCIPLES

- 2.1 Institutions shall inform students, by means of handbooks and module literature, the means by which modules shall be assessed and the method of reassessment for redeeming a failure.
- 2.2 All formal written examinations sat at the Partner Institutions shall, so far as national practice allows it, be marked in the anonymous state. This means that Candidates in such examinations shall be identified only by their student number until such time as both first and double marking have been completed.
- 2.3 Partner institutions shall so far as possible, and in keeping with national practice, mark other forms of assessment in the anonymous state also. It is, however, recognised that feedback from certain elements of assessment form an integral part of the learning experience and that, for practical reasons, it might not be possible to follow the policy at all times. Methods of assessment, which involve observation, interaction and oral/aural elements, and in particular the Part II element of the degree, shall not be subject to anonymity.
- 2.4 Progression/ Examining Boards shall be presented with all marks of assessment undertaken during the term(s) concerned. Marks for modules of the scheme shall be recorded out of a hundred according to the marking criteria in 3 below.
- 2.5 Resit marks must be clearly identified in the presentation of marks to the Progression/ Examining Board.
- 2.6 All results will be disclosed to students electronically by CIMNE after the formal Progression/Award Boards.
- 2.7 To ensure consistency of marking within the Consortium a sample selection of examinations and course work will be double/ second mark. I.e. a member of staff from another institution within the Consortium or an external examiner, employed by the Consortium to ensure consistency of marking, will second mark a sample of work to ensure overall standards.
- 2.8 The Consortium will employ an external examiner i.e. a member of staff external to any of the institutions involved in the Consortium to review the scheme and ensure parity of marking and overall quality of the programme.

3. MARKING CRITERIA

Due to the Collaborative nature of the scheme, the Consortium is committed to the ECTS grading structure. Examinations and assessment will be marked out of a hundred. The marks equate to ECTS grades as follows:

Mark	100 – 90	89 – 80	79 – 70	69 – 60	59 – 50	49 or less
ECTS	A/A+	B	C	D	E	F/FX
Descriptor	Excellent . (outstanding performance with only minor errors.)	Very Good (above average standard but with some errors.)	Good (generally sound work with a number of notable errors.)	Satisfactory (fair but with significant shortcomings.)	Sufficient (performance meets the minimum criteria.)	Fail (Some/ Considerable work required before the credit can be awarded.)

4. MODULE RULES

- 4.1 Modules shall be assessed individually, as prescribed by the relevant institution(s). The assessment method of a module may take the form of an unseen written examination paper, set projects or other course work assignments, but must be appropriate to assess whether a student has met the learning outcomes of the module. A student may also be required to demonstrate to the appropriate examining board, satisfactory completion of any period of professional training or practical experience, failure of which may lead to failure of the module, despite a mark of 50 having been gained for the other assessed work.
- 4.2 In addition to satisfying the assessment requirements of a module, each student must satisfy the attendance requirements as stated in the handbook. It is the responsibility of Institutions to monitor satisfactory attendance and assessment in each module. Students who do not satisfy the attendance and assessment requirements of a module will be reported to the appropriate Board in the partner institution concerned.
- 4.3 A mark will be assigned to each student, based on his/her performance.
- 4.4 The Pass mark for modules will be set at 50. Credits will be awarded to candidates who pass a module. All modules pursued must be passed. (However, see 4.5 below).
- 4.5 The Progression Board may award a compensatory pass in the light of extenuating circumstances, which contributed, adversely to the student's performance in the assessment exercise (a mark of 50 shall be recorded for a compensatory pass). The Examining Board may award compensatory passes in up to 10 ECTS credit points in each term in Part I as long as the mark in each module considered for a compensatory pass is 40 or above.

- 4.6 The late submission of assessed work shall result in a mark of 0 being awarded and a decision of fail being recorded, unless an extension has been granted prior to the deadline. There are no other penalties.

5. PROGRESSION RULES

Progression from Term 1 to Term 2

- 5.1 A Progression Board shall be held in Barcelona at the end of the first term to determine whether or not students qualify to proceed to the second term, to be pursued at another designated institution within the Consortium.
- 5.2 Students must accumulate 30 ECTS credits (by passing modules with a mark of 50 or better in each module) to progress to Term 2.
- 5.3 Students whose performance is deemed, by the Progression Board, to be extremely weak (i.e. who accumulate less than 10 ECTS credits on their first attempt at a term) will FAIL to proceed further and will not be given an opportunity to redeem their failures.
- 5.4 Students who fail a module(s), but have accumulated 10 ECTS or more (by passing modules at 50 or above) will fail to progress and shall, at the discretion of the Progression Board, normally be permitted one further attempt usually at the start of the second term to redeem their failure in each such module.(See section 7 regarding the marking policy for redeemed modules.)
- 5.5 Students who are eligible to progress to the next term shall not be allowed to repeat any module for which credit has been awarded in order to improve their performance.
- 5.6 Students who fail to complete the term have the right of appeal in accordance with the appeals procedure adopted by the Consortium Board of Studies.

Progression from Part 1 (end of term 2) to Part 2 (terms 3 & 4)

- 5.7 Each Partner Institution shall hold a Progression Board at the end of the second term to determine whether or not students qualify to proceed to Part II (the third and fourth term) at the same institution.
- 5.8 Students who accumulate 60 ECTS credits, by passing all modules during Terms 1 and 2, shall have been deemed to have passed Part I and shall qualify to proceed to Part II (3rd & 4th terms).
- 5.9 Students whose performance is deemed, by the Progression Board, to be extremely weak (i.e. who accumulate less than 10 ECTS credits on

their first attempt at term 2) will FAIL to proceed further and will not be given an opportunity to redeem their failure(s).

5.10 Students who fail a module(s), but have accumulated 10 ECTS or more in term 2 (by passing modules at 50 or above) will fail to proceed to the next term and shall, at the discretion of the Progression Board, normally be permitted one further attempt before the beginning of the third term to redeem their failure in each such module. (See section 7 regarding the marking policy for redeemed modules.)

5.11 Students must complete Part I of the scheme of study successfully (i.e. completion of Part I must be confirmed by a Progression Board) before being permitted to proceed to Part II (the dissertation / project stage).

5.12 Students who are repeating failed modules and who fail to qualify to proceed to the next term at the second attempt will be informed that they have failed the scheme but will be considered for an exit award where appropriate.

5.14 Students who fail to progress to Part II have the right of appeal in accordance with the appeals procedure adopted by the Consortium Board of Studies.

5.15 To qualify for an award, students must accumulate credits as follows:

Postgraduate Diploma in Computational Mechanics	60 ECTS credits
Master's Degree in Computational Mechanics	120 ECTS credits

6. UNFAIR PRACTICE

6.1 Students must ensure that they do not engage in any form of unfair practice, whereby they take action which may result in them obtaining for themselves or others, an unpermitted advantage.

6.2 Unfair practice is defined as any act whereby a person may obtain for himself/herself or for another, an unpermitted advantage. This shall apply whether candidates act alone or in conjunction with another/others. An action or actions shall be deemed to fall within this definition whether occurring during, or in relation to, a formal examination, a piece of coursework, or any form of assessment undertaken in pursuit of the Erasmus Mundus MSc in Computational Mechanics.

6.2.1 Examples of unfair practice in examination conditions are as follows:

- introducing into an examination room any unauthorised form of materials such as a book, manuscript, data or loose papers, information obtained via an electronic device such as a programmable calculator, pager, mobile phone, hand held computer or any source of unauthorised information;
- copying from or communicating with any other person in the examination room, except as authorised by an invigilator;

- communicating electronically with any other person;
- impersonating an examination candidate or allowing oneself to be impersonated;
- presenting evidence of special circumstances to examination boards which is false or falsified or which in any way misleads or could mislead examination boards;
- presenting an examination script as your own work when the script includes material produced by unauthorised means. This includes plagiarism.

6.2.2 Examples of unfair practice in non-examination conditions are as follows:

- Plagiarism. Plagiarism can be defined as using without acknowledgment another person's work and submitting it for assessment as though it were one's own work, for instance, through copying or unacknowledged paraphrasing (see 6.2.3 below);
- Collusion; Collusion can be defined as involving two or more students working together, without prior authorisation from the academic member of staff concerned (e.g Programme leader, lecturer etc) to produce the same or similar piece of work and then attempting to present this work entirely as their own. Collusion may also involve one student submitting the work of another with the knowledge of the originator.
- Commissioning of work produced by another;
- Falsification of the results of laboratory, field-work or other forms of data collection and analysis.

6.2.3 Examples of plagiarism are as follows:

- use of any quotation(s) from the published or unpublished work of other persons which have not been clearly identified as such by being placed in quotation marks and acknowledged;
- summarising another person's ideas, judgements, figures, software or diagrams without reference to that person in the text and the source in the bibliography;
- use of the services of 'ghost writing' agencies in the preparation of assessed work;
- use of unacknowledged material downloaded from the Internet;
- submission of another student's work as your own;

6.3 Students suspected of having engaged in unfair practice or assisting another student to engage in unfair practice, either in coursework or examination will be subject to the unfair practice procedures at the institution in which they are studying.

6.4 Institutions will investigate any cases of unfair practice identified at their institution, by means of their usual procedures and inform the Consortium of their results.

- 6.5 Students accused of engaging in unfair practice will be given an opportunity either in writing or person to present their case.
- 6.6 Students found guilty of unfair practice will be subject to the following penalties:
- 6.6.1 The issue of a written reprimand to the candidate, a record of the reprimand should be kept;
 - 6.6.2 the text to be ignored when marking, resulting in a reduced mark;
 - 6.6.3 the cancellation of the candidate's marks for the assignment;
 - 6.6.4 the cancellation of the candidate's mark in the module concerned;
 - 6.6.5 the cancellation of the candidate's mark in the module concerned and the preclusion of redeeming the failure until the next academic session;
 - 6.6.6 the cancellation of the candidate's marks in all of the modules for the particular level of study;
 - 6.6.7 the cancellation of the candidate's mark in all of the modules for the particular level of study and the disqualification of the candidate from any future Consortium examination;
 - 6.6.8 In the event of a Institution deciding that the above penalties are inappropriate, the Institution may use its discretion to decide upon an appropriate penalty.
- 6.7 The Institution should consult the student's case history and academic record before imposing a penalty. In order to ensure consistency in the application of penalties, the Consortium will develop a guidance note/ Code of Practice on the normal penalties for Unfair Practice. The normal penalty for unfair practice in non-examination conditions (1st offence) shall be the cancellation of the candidate's mark(s) in the module(s) concerned. However, the Institution may wish to take into consideration the seriousness of the offence and impose a harsher penalty in accordance with the Code of Practice. Alternatively it might take into account mitigating circumstances. The Institution should be convinced that the mitigating circumstances have a direct bearing on the case and, in particular, had influenced the action of the student concerned.
- 6.8 Students have the right of appeal, against substantiated allegations of Unfair Practice, in accordance with the appeals procedure adopted by the Consortium Board of Studies.

7 REDEEMING A FAILURE

- 7.1 Students who fail a module in the first or second term will fail to progress and shall, at the discretion of the Progression Board, normally be permitted one further attempt before/ shortly after the beginning of the next term to redeem their failure in each such module, provided that this can be achieved within the time limit for the degree. The mark for this further attempt shall be up to the capped threshold of 50 in each such module, irrespective of their actual level of performance.

- 7.2 With regards students who fail a module the Progression Board has the discretion to allow a student to:
1. be re-examined in the module as a whole (mark capped at 50, final attempt); or
 2. be re-examined in those parts of the module which he/she has failed where more than one piece of work contributes towards the final module mark. (mark capped at 50, final attempt)
 3. be re-examined without any restriction on mark. This would only be allowed where the student has demonstrated special circumstances to the Board. See section 8.
- 7.3 Students must not expect, as of right that they will be allowed to redeem failures, allowed to repeat failed modules or be allowed to continue. The Progression Board may take into account other circumstances relating to the candidate's case, such as attendance and performance in classes, before taking any progression decision. A Progression Board would not be expected to allow a candidate to progress unless he/she had satisfied the minimum criteria and demonstrated competence to undertake work required at the next stage.
- 7.4 A candidate who is to be re-examined in set projects or other forms of course assessment shall not be permitted to re-submit modified versions of his/her original work, but shall be required to submit for examination new work on different topics from those, which originally failed to satisfy the examiners.
- 7.5 Candidates who are attempting to redeem a failure and who fail on the second attempt, will be informed that they have failed the scheme but will be considered for an exit award where appropriate.
- 7.6 Candidates who pass the failed modules and accumulate at least 30 ECTS credits, at 50 or above, in modules at the appropriate Level qualify to proceed to the next Term.
- 7.7 The Consortium reserves the right to charge a re-submission / re-examination fee in respect of failed modules or the re-submission of a dissertation.

8 EXCEPTIONAL CIRCUMSTANCES

- 8.1 A student who is absent for the whole of a written examination (or who fails to submit set projects or coursework by the required date(s)) will be deemed to have failed the modules(s) in question. In the case of illness or other exceptional circumstances, the Progression Board may grant an extension to the submission date or permit a supplementary examination to be held as appropriate. It is recognised that the marks of such students will not be subject to the ceiling of 50. They will be considered as 'First Sit' students, which mean that they will be marked according to the same grading scale as students who attempt the examinations/

course work for the first time. The mark(s) of such candidates shall be considered at the “Supplementary Exam Board”.

- 8.2 Students who attend an examination/ submit coursework as directed but fail a module due to illness or other exceptional circumstances may, at the discretion of the Progression Board, be allowed to sit the examination/submit course work again, as a ‘First-sit’ candidate. This means that they will be treated in the same way as students who take the examinations/ submit the coursework for the first time and their marks will not be capped (i.e. not subject to a ceiling of 50). The mark(s) of such candidates shall be considered at the “Supplementary Exam Board”.
- 8.3 Students who miss a submission deadline/ are absent from an examination or who fail a piece of coursework or an examination due to illness or other exceptional circumstances should notify the course leader at the institution in which they are studying before the examination or deadline for submission or if this is not possible as soon after the examination/ deadline as is possible and before the date of the examination board. To be considered as a ‘First Sit’ candidate the student will need to provide written evidence (for example medical certificates) to the Board.
- 8.4 In the same way as students who fail modules at the first attempt ‘First Sit’ candidates who have failed modules shall be allowed to redeem failures at the next available opportunity, usually by carrying the modules and resitting them the following year, by:
1. being re-examined in the module as a whole (mark capped at 50, final attempt); or
 2. being re-examined in those parts of the module which he/she has failed (mark capped at 50, final attempt)

9 SPECIFIC RULES – PART II

INDUSTRIAL PROJECT

- 9.1 Practical training (Industrial project) is an essential element in the curriculum providing inside knowledge in computational mechanics project development and management. Professional or R+D profiles will be provided in industry or in applied research organizations which are in close collaboration with all institutions in the Consortium. This training can be closely related to the Master’s thesis.
- 9.2 The student will be given a nominated contact within the placement generally a line manager. The student will also be assigned a tutor at the Institution.

- 9.3 The Industrial project is worth 15 ECTS and will last for at least 7 weeks of full-time dedication (or an equivalent period)
- 9.4 It can take place any time during the 3rd and 4th term, in agreement with the host institution for this period.
- 9.4 There will be no mark for the industrial project. It will be graded as pass or fail.
- 9.5 Due to the nature of the project there will be no mechanism for redeeming a failure should a student fail.
- 9.6.1 Students who fail the industrial project, will be informed that they have failed the scheme but will be considered for an exit award where appropriate.
- 9.7 Students who fail to complete the industrial project have the right of appeal in accordance with the appeals procedure adopted by the Consortium Board of Studies.

DISSERTATION/ THESIS

General Principles

- 9.8 A supervisor will be appointed for each candidate who will be responsible for ensuring that studies are carried out in line with the institution's good practice guidelines.
- 9.9 Normally, no designated supervisor who has been involved in the preparation of the dissertation shall act subsequently as an examiner for it.
- 9.10 The student should submit three typed copies and one electronic copy of the dissertation to the Exam Co-ordinator, in the format prescribed by the Consortium Board of Studies and notified to the student by the institution at which the dissertation takes place..
- 9.11 Dissertations submitted for examination shall normally be openly available and subject to no security classification or restriction of access. However Partner Institutions may, place a bar on photocopying of and/or access to a dissertation for a specified period of up to five years. It shall be the responsibility of the candidate's project supervisor to make an application to the Consortium Board of Studies and any appropriate body in the partner institutions as soon as possible and before the result is known. This request will be reported to the Part II Award Board.

- 9.10 A candidate is at liberty to publish the whole or part of the work produced during the candidate's period of enrolment at the Institution, prior to its submission as a whole, or as part of a dissertation, provided that in the published work it is nowhere stated that it is in consideration for a higher degree. Such published work may later be incorporated in the dissertation submitted for examination.
- 9.11 Retention and disposal of a dissertation shall be in accordance with the policy of the awarding institution.

Examination

- 9.12 Due to national differences in the countries making up the Consortium, the marking criteria and assessment rules (for instance the length of the dissertation and the requirement to make a public or private defence) for the dissertation/ thesis element of the degree will vary slightly depending on which institution the student completes his/ her dissertation in. Students should familiarise themselves with the regulations of the institution in which they submit their dissertation.
- 9.13 In all institutions the Dissertation will be examined by both an internal examiner (who will not be the student's supervisor) and an external examiner (who may be a member of staff from another institution within the Consortium). The marking structure followed will be in accordance with national rules and will reflect the marking structure for final award detailed in section 11 below.
- 9.14 If a dissertation is failed by the examiners, the candidate may re-present it once only, not more than twelve months from the date of the official communication to the candidate of the result. A fee shall be payable to the Institution concerned for the examination of such a re-presented dissertation.
- 9.15 At Part Two, a candidate who fails to submit the dissertation/project by the deadline specified for the scheme, and who has not been granted an extension of candidature due to special circumstances will fail the degree.

10 EXTENSIONS OF CANDIDATURE DUE TO SPECIAL CIRCUMSTANCES
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- 10.1 The time limit for the completion of the degree may be extended in exceptional cases only. A reasoned application, supported by appropriate independent evidence, must be submitted by the candidate's tutor for consideration, to the Consortium Board of Studies, and any appropriate institutional academic committees.

Requests for an extension shall be considered with reference to the following criteria:

- (a) Normally, suspensions / extensions will be granted only on compassionate grounds, or in cases of illness, serious domestic difficulties or exceptional commitments, which can be demonstrated to have adversely affected the candidate. A full and reasoned case, supported by appropriate, satisfactory, medical or other independent evidence, and a work-plan for completion of the thesis within the extension requested, must be made by the department for consideration by the Consortium Board of Studies, in the first instance, and thereafter by the appropriate committee of the awarding institution.
- (b) In cases which arise as a result of illness:
- (i) Satisfactory medical or other relevant documentary evidence must be supplied. (The extent and nature of the illness as described in the certificate are invaluable in assessing the case.)
- (ii) A clear statement must be supplied, showing that the institution concerned has evaluated the situation in which the candidate finds himself / herself as a result of the illness and that it considers the requested extension to be appropriate for completion in accordance with the work-plan. Such a statement will, wherever possible, follow direct contact between candidate and institution.

11 FINAL AWARD

- 11.1 At the end of the fourth term, the final Joint Award Board for all students will be held at one of the partner institutions to determine award decisions on students pursuing all Erasmus Mundus Master's schemes offered by the Consortium. The Board shall be attended by representatives from each Institution and a Senior External Examiner, appointed by the Consortium Board of Studies to be responsible for overseeing the schemes overall. It will be serviced by a senior administrative officer from one of the partner institutions.
- 11.2 The students' overall performance on the schemes shall be considered and the remit of the Board will be to:
- receive notification and formally endorse Part II results;
 - receive notification and formally endorse any requests for Bar's on Access;
 - to determine the overall award and in particular to consider cases of candidates who might be eligible for the awards of Distinction/ Merit in the UK, Matricula de honor/ sobresaliente in Spain, Très Bien/ Bien in France or 1-1.5 in Germany;
 - consider statistical data on all schemes offered by the consortium;
 - conduct an annual review of all schemes.

- 11.3 The full set of results for each candidate considered at a Part II Award Board, shall be presented to the examiners. The result profile of the relevant students will include:
- the Part I results, also including the Part I average and the Part I decision;
 - the results of the dissertation;
 - the results of the industrial project;
 - an indication of any failures in modules at the first attempt (as this will influence whether a student will be eligible for the highest grade in the UK.)
- 11.4 Both Parts of the degree must be completed successfully before a candidate may qualify for the award of a degree
- 11.5 A candidate's Part I results may not be subsequently reviewed to determine the outcome for the whole scheme.
- 11.6 A candidate who has failed any module at the first attempt of the examination shall not subsequently be eligible for the award of Distinction or merit in the UK, irrespective of the level of his/her performance in any subsequent assessment.
- 11.7 Appeals against award decisions shall be considered in accordance with the appeals procedures adopted by the Consortium's Board of Studies, and administered by the partner institution concerned in conjunction with their own awarding institutional regulations.
- 11.8.1 Successful students will be awarded a double Masters degree from both the first and second institution in which they study, until a joint degree can be awarded.
- 11.9 Degrees will be awarded according to national assessment structures, namely:

United Kingdom	Distinction (Candidates who pass all modules at the first attempt and achieve an overall mark of not less than 70% for the whole scheme, having achieved 65% or more in part I and 70 (UK marking rules– ECTS A/B) in Part II, shall be eligible for the award of a Master's Degree with Distinction.)		Merit (Candidates who pass all modules at the first attempt and achieve an overall average mark of not less than 60% and not more than 69.99% for the whole scheme, having achieved 60% or more in Part I and 60 (UK marking rules– ECTS C/D) in Part II, shall be eligible for the award of a Master's degree with merit.		Pass	Fail
Spain	Sobresaliente	Notable		Aprobado		Suspenso
France	Très Bien	Bien	Assez bien	Passable		Echoué
Germany	1.0-1.5	1.6-2.5	2.6-3.5	3.6-3.8	3.9-4.0	4.1-5.0

These equate to ECTS descriptors as follows:

ECTS	A/A+	B	C	D	E	F/FX
Descriptor	Excellent . (outstanding performance with only minor errors.)	Very Good (above average standard but with some errors.)	Good (generally sound work with a number of notable errors.)	Satisfactory (fair but with significant shortcomings.)	Sufficient (performance meets the minimum criteria.)	Fail (Some/ Considerable work required before the credit can be awarded.)

11.10 In order to be eligible for a Distinction in the UK, students must pass all modules at the first attempt and achieve an overall average mark of not less than 70% for the whole scheme, having achieved 65% or more in Part One and 70% or more in Part Two.

11.11 In order to be eligible for a Merit in the UK, students must pass all modules at the first attempt and achieve an overall average mark of not less than 60% and not more than 69.99% for the whole scheme, having achieved 60% or more in Part One and Two.

10. THE VIRTUAL CENTER¹

The Virtual Centre of CIMNE provides a 24 hours 7 days a week forum for communication among students as well as with their teachers, regardless of their geographical location, and administrative staff. The Virtual Centre also hosts web based course content made available to the students for each module. Most of the existing modules have been developed over a number of years in each of the Institutions making up the Consortium and a significant amount of high-quality web based course content is available. The Virtual Centre also provides mechanisms for disseminating official notices of the consortium and obtaining student feedback.

The course material includes lecture notes and some textbooks. A collection of examples and exercises will be provided as well as computer codes introducing the students to the finite element method in practical applications.

11. STUDENT SERVICES AND RELEVANT CONTACT INFORMATION

For questions related to the Master's course students should contact:

Master's Secretariat

International Center for Numerical Methods in Engineering (CIMNE)
Edificio C1, Campus Norte UPC, Gran Capitán s/n
08034 Barcelona, Spain
Tel. + 34 -93 401 74 41, Fax + 34 -94 401 65 17
e-mail: science@cimne.upc.edu

For up-to-date information students should check:

www.cimne.com/cm-master

In addition, other useful links are:

In Barcelona

UPC Institutional and International Relations Office www.upc.edu/ari/english/home	Barcelona Centre Universitari http://www.bcu.cesca.es/angles/index.htm
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In Swansea

Postgraduate Office at University of Wales Swansea e-mail postgradoffice@swansea.ac.uk telephone 01792 295132.	International Office at University of Wales Swansea http://www.swan.ac.uk/international/
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In Nantes

International Relations at Ecole Centrale Nantes Building D, BP 92101, F-44321 Nantes Cedex 3, FRANCE international@ec-nantes.fr

¹ <http://www.cimne.upc.es/cdl>

In Stuttgart

Office of International Affairs at Universität Stuttgart

http://www.uni-stuttgart.de/ia/internat/index_eng.html

12. CURRICULUM

The Masters programme consists of four terms. It amounts to 120 ECTS credits and lasts for 2 academic years. Students attend two institutions: the first institution (either Barcelona or Swansea) is responsible for teaching 35 ECTS and the second institution (Stuttgart, Nantes, Barcelona or Swansea) the remaining 85 ECTS.

Table 1: Structure of the course

PART 1 (30+30 ECTS) Taught element		PART 2 (60 ECTS) Research- and practice-based element	
First Term	Second Term	Third and Fourth Terms	
1 st Institution	2 nd Institution	1 st Institution	2 nd Institution
Core modules 20 ECTS	Minor modules and electives 30 ECTS	Research Project Plan Assessment 5 ECTS	Master's thesis 40 ECTS
Electives 10 ECTS			Practical Training 15 ECTS
Research Planning²			

² Assessed and credited at the beginning of the third term in the Research Project Plan Presentation, after the thesis topic is assigned.

1.1 First term

The first term provides the fundamental background with four core modules amounting to 20 ECTS, as well as elective modules adding up to a total of 30 ECTS. Students will also receive preparation for their dissertation, in the form of a 5 ECTS module, “Research Planning”, which will be assessed at the start of the third term. The first term is simultaneously taught at Barcelona and Swansea, with identical core modules and a unified evaluation.

A joint Examination Board takes place at the end of the first term. Successful students move to a different institution in order to pursue the second term. At the start of the second term, institutions where the local language is not English offer language training modules to students.

1st Term Core Modules

Universitat Politècnica de Catalunya/CIMNE
University of Wales Swansea

Modules	ECTS
Numerical Methods for Partial Differential Equations	5
Finite Element Method	5
Continuum Mechanics	5
Computer Modelling	5

1st Term Elective Modules

Universitat Politècnica de Catalunya/CIMNE

Modules	ECTS
Seminar series in computational mechanics	3
Basic programming for engineers and scientists	3
Advanced programming for engineers and scientists	3
Pre and post-processing techniques in computational mechanics	4
Research Planning	(5) ³

1st Term Elective Modules

University of Wales Swansea

Modules	ECTS
Advanced Fluid Mechanics	5
Advanced Computational Techniques	5
Communication Skills for Research Engineers	(5) ³

³ Assessed and credited at the beginning of the third term in the Research Project Plan Presentation, after the thesis topic is assigned.

1.2 Second term

The second term can be pursued at any of the four partner institutions. It is organized in minors, consisting of a set of modules emphasizing, or bearing particular relevance to, a specific area in Computational Mechanics. Each institution offers two minors (cf. Table 2), the contents of which are adapted to its expertise, and defines the compulsory and elective modules for each minor. While some modules fall strictly within one minor, other modules deal with transversal advanced topics relevant to more than one minor.

The student must choose a partner institution for the second term, different from that where he/she conducted the first term. In agreement with the local requirements of the second institution, the student must select a set of modules adding up to 30 ECTS, in such a way that at least 15 ECTS qualify for a minor.

Table 2: Institutions providing each part of the structure and their corresponding expertise

Institution	First term 30 ECTS	Second term 30 ECTS					Third and fourth terms 60 ECTS	
		Solid Mechanics	Structural Engineering	Fluid Mechanics	Engineering Hydrodynamics	Engineering Materials	Research Planning	Master's thesis and practical training
UPC/CIMNE	X	X		X			X	X
UWS	X		X	X			X	X
ECN			X		X			X
U. Stuttgart		X				X		X

2nd Term Modules

Universitat Politècnica de Catalunya/CIMNE

Compulsory modules	Total ECTS	Solids Mechanics ECTS	Fluid Mechanics ECTS
Computational solid mechanics	4	4	
Finite elements in fluids	4		4
Computational structural mechanics and dynamics	4	4	
Computational wave propagation	4	1	3
Computer assignment	4	2	2

Elective modules (subject to timetable constraints and availability)

to be chosen as to complete at least 15 ECTS in a specialization

Seminar series in Computational Engineering and Applied Sciences	3	2	2
Advanced discretization methods	3	2	2
Optimization	2	2	2
Verification and Validation	2	2	2
Coupled problems	2	1	1
Computational contact mechanics	2	2	
Multiscale computational mechanics	2	2	
Computational material failure	2	2	
Computational geomechanics	2	2	
Computational multibody dynamics	2	2	
Fluid-structure interaction in fast transient dynamics	2		2
Mathematical problems for environmental problems	2		2
Computational fluid dynamics	3		3

2nd Term Modules

University of Wales Swansea

30 ECTS to be chosen, at least 15 from one subject specialisation

Structural Engineering

ECTS

Dynamics of Structures	5
Computational Plasticity	5
Advanced Structural Analysis	5
Nonlinear Continuum Mechanics	5

Fluid Mechanics

Computational Fluid Dynamics	5
Fluid Structure Interaction	5
Reservoir Simulation	5
Computational Electromagnetics	5

Other (subject to timetable constraints and availability)

Advanced Structural Analysis	5
Water Systems Supply and Computational Simulation	5
Optimisation	5
Engineering Design Optimisation	5
Computational Intelligence in Engineering	5

2nd Term Modules

Ecole Centrale de Nantes

Compulsory modules	Total ECTS	Structural Eng. ECTS	Eng. Hydro-dynamics ECTS
eXtended Finite Element Method and Level Set techniques	3	3	
Multi-Scale Structural Analysis	3	3	
Materials Modelling for Numerical Simulations	4	4	
Fluid Mechanics	5		5
Numerical techniques for PDEs in fluids	5		5

Elective modules

Computational Damage and Fracture Mechanics for Composites and Polymers	5	5	
Durability of Concrete Structures	5	5	
Numerical and physical modelling strategies for viscous naval hydrodynamics	5		5
Computational methods for incompressible flows and applications to optimization and flow control	5		5

2nd Term Modules

Universität Stuttgart

Elective modules	Total ECTS	Solid Mechanics ECTS	Eng. Materials ECTS
Advanced Computational Mechanics of Structures*	6	6	-
Boundary Elements Methods in Statics and Dynamics*	6	6	-
Engineering Materials: Metals [#]	2	-	2
Engineering Materials: Concrete [#]	3	-	3
Engineering Materials: Soils [#]	2	-	2
Foundations of Porous and Multiphase Continua	6	4	2
Micromechanics of Materials and Homogenization Methods	6	2	4
Software Development and Numerical Programming	6	3	3
Adaptive Systems	6	3	3
Theory and Numerics of Materials at Large Strains	6	2	4
Numerical Algorithms for ODE and Linear Systems	6	3	3

* Mandatory modules for the Solids and Structures minor.

[#] Mandatory modules for the Engineering Materials minor.

1.3 Third and fourth terms

The third and fourth terms are devoted to the **Research Planning module** (5 ECTS), the **Master's thesis** (40 ECTS) and the **Practical training** (15 ECTS).

At the beginning of the second academic year, the student presents a **Research Project Plan** as part of the assessment for the Research Planning module (5 ECTS), which is taught at the first institution, elaborating on the assigned thesis topic and describing the proposed research plan. The presentation takes place in Barcelona coinciding with the induction weekend for the first-year students, in front the Board of Studies. The students are registered for these credits in the first-term institution.

The **Master's thesis** (40 ECTS) can be research or industry oriented. The student carries out the thesis in the same institution where he/she took the second taught term, so that he/she can choose a topic related to one of his/her areas of specialization. The master thesis includes the seminar series in computational mechanics developed in each institution during the 2nd academic

year. These seminars will be compulsory for senior students. The thesis should be submitted by end of May to the second academic session. Once completed, the Master's thesis will be defended in front of a local committee, with the external assessment of at least one faculty member of another institution of the consortium. The final mark of the thesis will be awarded by the Board of Studies of the Master's Programme during its summer meeting.

Practical training (15 ECTS) is an essential element in the curriculum providing students with the opportunity to apply their skills and knowledge in computational mechanics in an industrial context.

Students will be placed in engineering industries, consultancies or research institutions that have an interest and expertise in computational mechanics and will carry out an agreed practical project either during a single continuous placement of 7 weeks or via an equivalent series of shorter visits. The nature of the project will very much depend on the placement but can involve structural mechanics, solid mechanics, fluid mechanics or hydrodynamics. Typically, students will be trained by the relevant industry in the use of their in-house or commercial computational mechanics software. The outcome of this project will be a report and a presentation to be completed before the end of May. The report and presentation will be assessed by two internal examiners who will also consider a formal written report submitted by the industrial supervisor.

At the end of the module students should have gained expertise on the application of computational mechanics in an industrial context. The project should allow them to appreciate the practical aspects of computational mechanics and the way in which is being used in industry to solve real engineering problems. Students will gain knowledge and expertise on the use of the particular range of commercial software used in the industry where they are placed. At the end of the module students should be capable of writing a comprehensive technical report on the work developed and present it to a small audience.

Table 3: Student Calendar

	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug.
					Application deadline		Acceptance letter			Registration period		
1 st Academic Year	Induction Weekend				1 st term exams	Mobility				Thesis assignment deadline		
		1 st term (30 ECTS)					2 nd term (30 ECTS)					
	Research Project Plan presentation	Research towards Master's thesis (40 ECTS)							Thesis submission deadline	Thesis defense deadline		
2 nd Academic Year		Practical training (15 ECTS) at any time in agreement with 2 nd institution										
	5 ECTS credited to 3 rd term	3 rd term (25 ECTS)				4 th term (30 ECTS)						
		Fall Board Meeting				Winter Board Meeting				Summer Board Meeting		

13. PRACTICALITIES

Health insurance

EU-citizens

Information may be obtained from the website:

http://europa.eu.int/comm/employment_social/healthcard/index_en.htm

European citizens who are traveling within the European Economic Area, (i.e. the European Union, Norway, Iceland and Liechtenstein) and Switzerland, for private or professional reasons will be given a European Health Insurance Card, which will simplify the procedure when receiving medical assistance during their stay in a Member State.

This document will facilitate access to health care during your stay abroad and will allow you to receive health care in accordance with the legislation of the country of stay (i.e. in some countries, it will allow you to receive free health care). It is obligatory for your appropriate health institution to deliver at your request a European Health Insurance card or equivalent document.

Students receiving Erasmus Mundus stipends

Students receiving Erasmus Mundus stipends are automatically insured by the European Commission while enrolled at the programme. An insurance card and an insurance policy will be given to you at the start of the course. For further information in the insurance provided by the Commission please visit

http://ec.europa.eu/education/programmes/mundus/insurance_en.html

INFORMATION ON UNIVERSITÄT STUTTGART

The Universität Stuttgart, founded in 1829, has integrated the socialsciences and the humanities with engineering to become an internationally wellknown future-orientated place of research and study. Today the university is made up of 140 institutes in 14 faculties, with 5.000 employees and approximately 18.000 students of which around 4.000 are international students.

The Universität Stuttgart holds a leading position in both basic and applied research and is proud of its tradition of close co-operation with industry as well as with other research institutions such as the Fraunhofer-Society for Production Engineering, the Baden-Württemberg Testing Center, and the German Aerospace Research Institute. These close relationships also stimulate important impulses for teaching at the university.

The Faculty of Civil- and Environmental Engineering consists of 36 professors, 125 teaching and research assistants and 1500 students in 16 institutes.

The university is now also offering various new degree courses, which have come about as a reaction to the continuously changing needs of the global job market as well as the results of globalization in education.

The University is made up of two main campuses, i.e. the Vaihingen-Campus and the Stadtmitte-Campus

The Vaihingen-Campus is located in the suburb of Vaihingen and hosts the faculties of Civil- and Environmental Engineering, Geography, Geology, Biology, Chemistry, Electrical Engineering, Energy Engineering, Manufacturing, Aerospace Engineering, Mathematics, Physics; the offices of other international MSc programs like MIP, WAREM, INFOTECH, PHYSICS, WASTE, GEOENGINE and COMMAS.

The Stadtmitte campus is located downtown Stuttgart and hosts the faculties of Architecture, Geography, Geology, and Biology, History, Social Sciences, Business, Philosophy, Electrical Engineering, Civil Engineering and Surveying, Energy Engineering, Manufacturing; and the administration of the Universität Stuttgart.

The two campuses are connected via S-Bahn (subway) S1, S2, and S3. To get to the Vaihingen Campus from downtown, take S1, S2 or S3 in the direction of Herrenberg, Flughafen, Vaihingen, or Böblingen and get off at Universität. To return downtown (Stadtmitte) take any of the trains (S1, S2, S3) going in the direction of Hauptbahnhof.

There are extensive libraries on both campuses. Also, each campus has its own food court, store, bank, travel agency, copy shop, etc. The food court not only serves as a place to obtain cheap, subsidized food, but is also a place to obtain information on housing, culture, etc.

HEALTH INSURANCE

To be enrolled successfully at the Universität Stuttgart, you have to prove that you are either in possession of a private health insurance which covers all potential costs in Germany or you join a statutory health insurance scheme.

Foreign students who are already over 30 years old at the commencement of their studies in Germany usually cannot contribute to a statutory health insurance scheme.

A statutory health insurance costs about 60 EUR/month.

VISUM

Obtaining a student visa for Germany usually requires at least two months. Therefore, apply for a student visa immediately upon arriving in Swansea or Barcelona and getting the Letter of Admission. The administration in Swansea and Barcelona will help you to arrange a date. The visa should be valid from January 2008. Do not enter Germany with a tourist visa, since a tourist visa cannot be transferred to a student visa once you have entered Germany.

The German Missions Abroad (www.auswaertiges.amt.de/www/en/adressen.html)

In your application, please refer to COMMAS, Erasmus Mundus-Program and include a copy of your acceptance letter. If your visa application is delayed, contact the COMMAS office for assistance.

If the Embassy/Consulate requires that you open a bank account in Germany, please get in contact with a German bank for further information. (Please note, these banks are listed only as examples, we leave the final choice up to you!)

Commerzbank(www.commerzbank.com)

Deutsche Bank(www.deutsche-bank.de)

Dresdner Bank(www.dresdner-bank.de)

LBBW Bank (has an on-campus office)

(www.lbbw.de/lbbw/html.nsf/webdokumente/start_english.htm)

Postbank(www.postbank.de)

Volksbank(www.vr-networld.de)

INFORMATION ON SPAIN

UPC's syllabuses are designed so as to address the educational needs of society. By adapting them to the changes taking place at the University and in society, they are submitted to a continuous process of revision and improvement. The syllabuses are divided into **curricular areas** and the first of these areas corresponds to the selection phase.

The **selection phase** is designed to evaluate students' ability to make satisfactory progress in the subjects they choose and to finish them in the length of time foreseen; for this reason, it includes both basic course materials and technological subjects specific to the qualification. Not all of the qualifications establish the selection phase at the same point during the course. There are one- and two-semester selection phases. Students must pass the selection phase in no longer than double the amount of time allotted to it: if the selection phase is one semester long, then the student must obtain a pass grade in a maximum of two semesters' time. This time limit does not apply to people who wish to work whilst undertaking their studies. In this case, they can request to take the selection phase under special conditions.

Most UPC Schools are located within the city of Barcelona. Its excellent location in terms of international communications, its Mediterranean climate and its cosmopolitan character are some of the characteristics which make of Barcelona a privileged city.

Barcelona has more than 2000 years of history. The history of its expansion from ancient times is marked on the walls of its buildings and streets. Its entire history is reflected in the present. The location and beauty of Barcelona go hand in hand with the warmth of its residents. Its tradition initiative, hard work and creativity are a result of the continuous influx of different peoples and cultures, which are fundamental to any hospitable and welcoming city. These factors have had an undeniable influence on the vitality of the population and its rich cultural and artistic history.

La Rambla is the main thoroughfare of Barcelona, as well as the city's most famous street. Roman walls can still be seen in the city centre. A good way to acquaint oneself with the city is to walk down La Rambla towards the port.

Along this route, visitors come across the impressive old town, with its palaces, churches, museums, squares, small peaceful corners and medieval alleys where Romanesque and Gothic styles coexist. The walls reveal Barcelona's history and the avenue presents us with the city's character.

The markets and bazaars give a touch of colour to the place and testify to its trading tradition. During the long summer months, the old town becomes a light-hearted, open-air celebration.

La Rambla ends at the sea. Restoration projects carried out in this area have rehabilitated Barcelona's sea front. Currently, the city has long beaches, new ports built for leisure, and extensive and beautiful open spaces in which to enjoy a pleasant moment. Continuing along the sea front towards the North, we discover the newest part of Barcelona: the Olympic Village, with buildings designed by reputable contemporary architects and modern street furniture. This is truly a unique area, and a good place to enjoy a walk by the sea front. In a matter of seconds we have gone from the oldest to the newest area of Barcelona.

To speak of Barcelona is to speak architecture, design, painting, festivals, museums, theatre, music, etc. The generations of artists and intellectuals who chose the city as a meeting point and source of inspiration have irrevocably marked Barcelona. Here we can find masterpieces by the main Modernista architects, Gaudí and Puig i Cadafalch: Parc Güell, La Pedrera, Palau de la Música, etc. The city's prized possessions include the Modernista paintings of Rusiñol and Casas, the Miró and Tàpies Foundations, the MACBA (Barcelona Museum of Contemporary Art) and the unique Romanesque art collections which can be found in the National Art Museum of Catalonia. Local theatre is rich, both in tradition and in renovation. During the summer, Barcelona becomes the Mediterranean capital of theatre and music thanks to the international GREC festival, which includes a variety of outdoor performances. During the rest of the year, other cultural and international festivals take place.

Additional information on Barcelona

At the following Internet address, detailed information can be found on Barcelona: www.bcn.es

There are several tourism offices in Barcelona. Here are some of them:

Barcelona Information and Tourism Centre

Plaza Catalunya, 17 (metro)
Telephone.: 34 906 301 282

Barcelona Information Center

La Rambla, 58
Telephone: 34 933 179 829

Sants Tourism Office

Estación ferroviaria de Sants

Telephone: 34 906 301 282

Barcelona's area of influence

Barcelona's area of influence extends to a network of cities surrounding Barcelona and includes the city itself. This extensive metropolitan area currently includes three million residents.

The future of this urban system is a topic currently being considered by experts at UPC, who are investigating sustainable development proposals. An increasing number of people are moving to different municipalities in Barcelona's area of influence to live, work or study. This is true for 45% of Catalonia's population.

Some of UPC's major campuses and schools are situated in cities located within Barcelona's area of influence: Terrassa, Sant Cugat, Castelldefels and Vilanova i la Geltrú.

All these are well communicated with the city of Barcelona. Travelling to Barcelona from Terrassa, Castelldefels, Sant Cugat and Vilanova takes only 30 minutes by metro or train and is permanently guaranteed. The Manresa campus is located a bit further away; None the less, 26 trains per day connect Manresa to Barcelona in only 70 minutes.

Although they are near Barcelona, these cities each have their own personality and have much to offer.

Climate

Barcelona enjoys a Mediterranean climate, in which extreme temperatures are rare. Average monthly temperatures are as follows (in Celsius):

january	9°	july	24°
february	10°	august	24°
march	12°	september	21°
april	14°	october	17°
may	17°	november	16°
june	21°	december	10°

The universities of Barcelona have an agreement with Barcelona Housing Service for Students, a specialist organisation in youth accommodation, for the purpose of finding accommodation.

Students are advised to contact Barcelona Housing Service for Students either via Internet, e-mail or fax in order to determine the most suitable type of accommodation available (shared flat, rented apartment or university residence hall), well in advance of their moving to Barcelona.

The staff at Barcelona Housing Service for Students will inform you of the different costs involved in each option. If you do this, you will be able to go straight to your chosen place of residence upon arrival in Barcelona.

RECEPTION OFFICE

The Reception Office provides information and practical orientation to foreign students. All students, when they arrive at UPC, should go straight to the Reception Office in order to start the Technical University of Catalonia (UPC) registration process.

Reception Office staff will inform foreign students about the registration process, language courses, medical insurance and the different services offered by the University. They will also show them how to get to the school where they will be studying.

Reception Offices:

Oficina de Mobilitat Internacional de Barcelona

(International Mobility Office)
C/Jordi Girona, 1-3, mòdul A4
08034 Barcelona
Campus Nord
Tel: +34-93 401 69 37
Fax: +34-93 401 74 02

oficina.mobilitat.internacional@upc.edu

INFORMATION ON SWANSEA

THE CITY

Cosmopolitan, convenient, contemporary- Swansea is a modern city with a maritime feel. Living here brings you all the benefits of living in a city, and the benefits of living by the sea.

From the Maritime Quarter with its beautiful marina scenery, exhibitions, places to eat and the beach beyond; to the town centre with its shops, multi-screen cinema featuring the latest film releases, bowling centre, museum, the Glynn Vivian Art Gallery and the Grand Theatre which presents live performances all year round and is one of Britain's finest regional theatres; there is always plenty to do.

At night, the city comes to life with its wide choice of clubs, bars and restaurants, many situated in the vibrant Wind Street, and the nearby village of Mumbles with its famous pub mile!

What makes the city of Swansea so easy is its manageable size. Nothing is too far away from the centre. Regular buses run to and from the city centre and good coach, rail and motorway connections provide excellent links to many other cities in the UK.

THE UNIVERSITY

Swansea University was established by Royal Assent (as University College of Swansea) in 1920. It currently offers degrees of the University of Wales at undergraduate and postgraduate level. The University Campus is set between acres of green parkland and miles of sea and sand. It is a truly stunning location, just a couple of miles from the city centre and within easy reach of the beautiful Gower countryside and beaches. Swansea's thriving academic community is made up of over 10,500 students, of which over 2,000 are postgraduates, studying a wide variety of subjects.

Mission Statement

The University's Mission for the period 2006-11 is:

Swansea University will provide an environment of research excellence, with research being undertaken that is internationally recognised and that informs all other activities at the University. Swansea University will deliver an outstanding student experience, with teaching of the highest quality, which produces graduates equipped for distinguished personal and professional achievement.

The University community will be a powerhouse for growth in the regional economy, and will greatly enrich the community and cultural life of Wales. It will contribute to the health, leisure and well-being of citizens in South Wales and beyond.

Academic Registry

Web: <http://www.swan.ac.uk/registry/>

The Academic Registry, located in the Stable Block of Singleton Abbey, administers the following key areas that may directly affect your time at Swansea:

In addition, any queries that might result in having to change your personal or academic details may have to be referred to the Academic Registry. (Email: academic.registry@swansea.ac.uk)

Accommodation

Swansea has a good range of accommodation for new postgraduate students and priority is given to international students. For further information about accommodation at Swansea see <http://www.swan.ac.uk/accommodation/>

Student Support Services

Student Support Services is part of the Student Services Directorate alongside Residential Services (Accommodation Office) and the English Language Training Service (ELTS). It offers a 'one-stop-shop' to provide information, advice and support to students and staff working with them. It comprises:

- Disability Office
- International Student Advisory Service (ISAS)
- Money Advice - Student Financial Aid Office
- Student Counselling Service

Contact details:

Tel: 01792 602000

Email: student.services@swansea.ac.uk

Web: <http://www.swansea.ac.uk/study/current/StudentSupportServices/>

Support Services Handbook

A Support Services Handbook is sent to all new students with enrolment instructions prior to the beginning of the academic year. This provides a comprehensive guide to support services throughout the University. Copies are sent to Schools and it is also available on the website at: <http://www.swansea.ac.uk/media/Media,4813,en.pdf>

International Student Advisory Service (ISAS)

Email: ISAS@Swansea.ac.uk

Web: <http://www.swansea.ac.uk/study/current/StudentSupportServices/ISAS/>

The International Student Advisory Service (ISAS) provides information, advice and support on non-academic matters to all international (non-UK) students and their dependants. They also produce an International Student Handbook which is available on the website above.

The service operates according to the UKCOSA/AISA Code of Ethics for those advising international students and the Rules and Code of Standards of the Office of the Immigration Services Commissioner.

Common areas of advice include UK immigration, travelling in the EU, financial hardship, employment regulations and visiting friends and family. ISAS operates the Home Office Batch Scheme to assist students with extending their visas, and arranges Police Registration on campus.

Specific induction sessions are arranged for international students. Students can drop in for advice on simple matters or make an appointment with an adviser to discuss more complicated matters in detail. The drop in service operates each weekday morning and appointments are scheduled in the afternoons.

Disabilities

Email: disability@swansea.ac.uk

Web: <http://www.swansea.ac.uk/study/current/StudentSupportServices/DisabilityOffice/>

The University Disability Office provides a wide range of support services for those with disabilities. The main office is based in the Student Support Services Department, Ground Floor, Keir Hardie and include:

- Disability Office Manager – service management and development
- Caseworkers - a comprehensive advice and information service for students from initial enquiries prior to application and throughout their chosen course of study.
- Dyslexia Tutor – one to one tutorials and group presentations & workshops for students with Specific Learning Difficulties

- IT Support Officer – a help desk service to resolve problems with specialist technology and training on specialist software packages
- Mental Health Coordinator – advice and information for staff and students, individual student support and coordination with NHS Mental Health Services
- Support Coordinator – coordinates non-medical support recommended in students assessment of needs reports e.g. notetakers, readers, mentors, subject specific support, sighted assistance etc.

Disability Services at Swansea also include:

- An Assessment and Training Centre, where students are able to receive an assessment of needs interview and report that considers the effects of students disability on study, makes recommendations for support (equipment, personal and consumable) and indicates the associated costs. The assessment report enables students to access the Disabled Students Allowance (DSA) from LEA's to fund the recommended support.
- The Recording for the Blind Centre, which works closely with colleagues in the Disability Office and Library and Information Centre to provide materials in Braille, large print and/or tape.

Web: <http://www.swan.ac.uk/lis/library/rcfb/>

Money Advice – Student Financial Aid Office

This office provides students with information, money advice and debt counselling. It also administers a range of funds that provide loans, bursaries and non-repayable grants for students who may be facing financial difficulties and can offer help and advice on the following:

- Student Loans
- Student Fees
- Higher Education Grant
- Welsh Assembly Learning Grants (ALG)
- Cross Border Funding
- Financial Contingency Fund (FCF) - Hardship Grants & Loans
- European and International Student Crisis Fund

Email: sfao@swan.ac.uk

Web: <http://www.swansea.ac.uk/study/current/StudentSupportServices/MoneyAdvice/>

Student Counselling Service *Email: student.counselling@swansea.ac.uk*

The University operates a free, confidential counselling service. The service gives individual counselling to those students who find that they are unable to study effectively or enjoy their life at university, whatever the cause – personal or academic. Counselling is provided by professionally qualified counsellors, working to the Ethical Framework of the British Association for Counselling and Psychotherapy.

For further information and a copy of the Student Counselling Services booklet visit the website at <http://www.swansea.ac.uk/counselling/>

Students Union

In addition the Student's Union operates an advice and support centre offering free confidential advice to all University students. For further information on what Swansea Students Union has to offer see <http://www.swansea-union.co.uk/>

Sports and Extra Mural Activities

For Sports Enthusiasts our modern sports centre includes a fully equipped gym, multi-purpose sports hall, squash courts and a climbing wall. Next to this you will find our state-of-the-art 50m Wales National Pool. Outdoor facilities include rugby, football, lacrosse, cricket pitches and tennis courts. In addition, surfing and canoeing conditions on the Gower beaches are excellent.

For Arts enthusiasts the Taliesin Arts centre, based in the heart of campus, offers a lively programme of drama, dance concerts and an eclectic mix of films, including award winning foreign language titles not usually shown in mainstream cinema.

Study Support

A list of on-line resources for Study Skills support for students has been established at:

<http://www.swansea.ac.uk/study/current/StudentSupportServices/StudyAdvice/>

Language Classes

Free academic language support classes are also offered by the Centre for Applied Languages. Courses include general English, academic writing and reading and general study skills.

These are just some of the services available to you during your time at Swansea. For further information on what is available see

<http://www.swan.ac.uk/businessandcareers/CampusServices/>

GENERAL REGULATIONS / ACADEMIC REGULATIONS

Whilst studying at Swansea University students must abide by the University's Academic Regulations and General Regulations, which are printed in the Academic Handbook for Taught Masters-Level Schemes of Study.

You will be given a copy of this handbook on arrival in Swansea. Please read the handbook carefully as it is in your interest to familiarise yourself with the regulations and procedures.

SAFETY REGULATIONS & EMERGENCY PROCEDURES

The University's Safety Regulations are available for consultation on the main departmental notice board.

COMPLAINTS

The University of Wales Swansea is committed to ensuring a high quality educational experience for its students, supported by appropriate academic, administrative and welfare support services and facilities. However there will be instances when students may feel dissatisfied with the teaching and learning, facilities or services provided by the University, or with the way the University, its students or its staff have acted or omitted to act. This may include unreasonable behaviour or an unsatisfactory level of service. It is expected that students and staff will make reasonable efforts to resolve matters at the outset and it is anticipated that the majority of complaints can be resolved satisfactorily on an informal basis.

However, should you wish to make a complaint, details can be found in the section of the Academic Handbook for Taught Masters-Level Schemes of Study 2008/2009 (which will be given to you at the commencement of your time in Swansea).

The University operates a three-tier complaints system.

Stage 1: Informal Complaint

Stage 2: In writing to the relevant Head of Department/ School

Stage 3: Registering a formal complaint with the Academic Registry through filling in a formal University Complaint form.

Syllabus of M.Sc. Modules

1st Term Core ModulesUniversitat Politècnica de Catalunya/CIMNE
University of Wales Swansea

Modules	ECTS
Numerical Methods for Partial Differential Equations	5
Finite Element Method	5
Continuum Mechanics	5
Computer Assignment	5

NUMERICAL METHODS FOR PARTIAL DIFFERENTIAL EQUATIONS		
Credits: 5 Term: 1 Compulsory: YES		
Format :	Lectures	25h
	Examples	15h
	Private study	98h
Lecturers: S. Fernandez-Mendez, I. Arias, A. Huerta		
Contents:		
<p>This module presents the fundamentals of modern and classical numerical techniques for linear and nonlinear partial differential equations, with application to a wide variety of problems in science, engineering, and other fields. Topics include Finite Difference, Finite Volume and Boundary Element discretizations, and an overview of direct and iterative methods for systems of equations as well as a basic review of numerical methods for eigenvalue problems.</p> <ol style="list-style-type: none"> 1. Overview of partial differential equations 2. Finite difference methods for elliptic equations 3. Finite difference methods for parabolic equations (including consistency, stability and convergence issues) 4. Finite difference methods for hyperbolic equations 5. Introduction to finite volumes 6. Introduction to integral equation methods and boundary elements 7. Solution techniques: <ol style="list-style-type: none"> a. Direct solution methods and their implementation b. Iterative solvers (stationary and Krylov methods) c. Overview of techniques for Eigenvalue problems 		
Intended Learning outcomes: to demonstrate		
A knowledge and understanding of:	the fundamentals of the behaviour and numerical approximation of partial differential equations; truncation error and solution error; consistency, stability and convergence; direct and iterative solution of linear systems of equations and eigenvalue problems.	
an ability to: (thinking skills)	understand and formulate basic numerical procedures and solve illustrative problems; identify the proper methods for the corresponding PDE.	
an ability to: (practical skills)	understand practical implications of behaviour of numerical methods and solutions; logically formulate numerical methods for solution by computer with a programming language (Matlab, Fortran 77 or C).	
an ability to: (key skills)	study independently; use library resources; use a personal computer for basic programming; effectively take notes and manage working time.	
<p>Assessment: 30% continuous assessment assignments, 70% from end of Term examination (50% open-book). Practical Work: Exercises will be set, which will involve coding some of the presented methods.</p>		
<p>Recommended texts: Lecture notes Hoffman, J.D., <i>Numerical Methods for engineers and scientists</i>, McGraw-Hill, 1992 Smith, G.D., <i>Numerical Solution of Partial Differential Equations</i>, Oxford University Press, 1986</p> <p>Further readings: Leveque, R., <i>Numerical Methods for Conservation Laws</i>, Lectures in Mathematics, ETH Zürich, 1992</p>		

FINITE ELEMENT METHOD		
Credits: 5 Term: 1 Compulsory: YES		
Format :	Lectures	25h
	Examples	15h
	Private study	98h
Lecturers: E. Oñate, P. Diez		
Contents:		
<p>This module introduces the basic concepts of the Finite Element Method (FEM), including derivation of formulations, analysis of the resulting methods and essential aspects of the implementation. The presentation is motivated by linear practical problems (heat transfer, elasticity, etc.) and it is illustrated and complemented with hands-on applications. The module also includes an introduction to other topics such as transient problems, convection dominated problems, error assessment and adaptivity.</p> <ol style="list-style-type: none"> 1. Weighted residuals 2. Rayleigh-Ritz 3. Boundary conditions (matrix transformation, Lagrange multipliers, penalty, Nitsche) 4. Finite element discretization 5. Isoparametric transformation, numerical integration, 6. Introduction to finite element implementation 7. Introduction to transient problems (modal analysis and method of lines) 8. Error estimation and adaptivity 		
Intended Learning outcomes: to demonstrate		
a knowledge and understanding of:	the fundamentals of linear finite elements; the derivation of weak forms and their resolution; why finite elements approximate the solution of a PDE; the basic structure of a FE code; how to solve transient problems.	
an ability to: (thinking skills)	identify the key issues when performing a finite element analysis of an engineering problem; employ appropriate order polynomials together with appropriate integration rules; identify different methods for prescribing boundary conditions.	
an ability to: (practical skills)	solve linear solid mechanics and heat transfer problems by hand using FE; use a simple FE computer code to set up and produce results for computational simulation of simple engineering problems; formulate and implement simple key aspects of a FE code.	
an ability to: (key skills)	study independently; use library resources; use a personal computer for solving FE problems and do some basic programming; effectively take notes and manage working time.	
<p>Assessment: 30% continuous assessment assignments, 70% from end of Term open-book examination</p> <p>Practical Work: Exercises will be set which will involve use of a FE program and some coding.</p>		
<p>Recommended texts: Lecture notes Zienkiewicz, O.C.; Morgan, K., <i>Finite elements and approximation</i>, Wiley, 1983 Hughes, T.J.R., <i>The finite element method</i>, Prentice-Hall, 1987</p> <p>Further readings Henwood, D.J., Bonet, J., <i>Finite elements – A gentle introduction</i>, Macmillan, 1997 Zienkiewicz, O.C.; Taylor, R.L., <i>The finite element method: 1 basic formulation and linear problems</i>, Elsevier, 2005</p>		

CONTINUUM MECHANICS		
Credits: 5 Term: 1 Compulsory: YES		
Format :	Lectures	25h
	Examples	15h
	Private study	98h
Lecturers: C. Agelet de Saracibar, A. Rodriguez-Ferran		
Contents:		
A fully comprehensive module on nonlinear continuum mechanics for engineers with an in-depth review of fundamental concepts, including motion, descriptions, strains, stresses, balance laws, variational principles and an introduction to computational plasticity.		
<ol style="list-style-type: none"> 1. Tensor algebra and analysis (definitions, invariants, gradient, divergence, curl, integral theorems,...) 2. Kinematics: movement and deformation (deformation tensors) 3. Small strains and compatibility 4. Stress tensors 5. Balance principles 6. Constitutive theory (laws of thermodynamics, strain energy, elasticity) 7. Boundary value problems of linear elasticity (2D) 8. Introduction to plasticity (von Mises, Tresca, Mohr Coulomb) 9. Ideal fluids and potential flow 10. Viscous incompressible flow (with an introduction to turbulence) 		
Intended Learning outcomes: to demonstrate		
a knowledge and understanding of:	fundamentals of solid mechanics with application to elasticity; fundamentals of fluids mechanics.	
an ability to: (thinking skills)	understand different aspects (geometry, equilibrium and constitutive theory) of formulating engineering problems in solid and fluid mechanics, realize the difficulties in obtaining closed form solutions and a necessity for approximation techniques.	
an ability to: (practical skills)	develop practical skills related to tensor calculus; formulate and perform analysis of several classes of engineering problems in solid and fluid mechanics.	
an ability to: (key skills)	study independently; use library resources; effectively take notes and manage working time.	
Assessment: 70% from end of Term examination (40% use of lecture notes allowed), 30% by course work.		
Recommended texts: Lecture notes Holzapfel, G.A., <i>Nonlinear solid mechanics, a continuum approach for engineering</i> , Wiley, 2000 Currie, I.G., <i>Fundamentals mechanics of fluids</i> , 2 nd edition, McGraw Hill, 1993.		

1st Term Elective Modules

Universitat Politècnica de Catalunya/CIMNE

Modules	ECTS
Seminar series in computational mechanics	3
Basic programming for engineers and scientists	3
Advanced programming for engineers and scientists	3
Pre and post-processing techniques in computational mechanics	4
Research Planning	(5) ⁴

⁴ Assessed and credited at the beginning of the third term in the Research Project Plan Presentation.

COMPUTER ASSIGNMENT		
Credits: 5 Term: 1 Compulsory: YES		
Format :	Lectures	10h
	Computer laboratory	20h
	Private study	108h
Lecturers:		
Contents:		
Tutored weekly class where case studies and practical examples are reproduced by the students. Topics covered by the other modules are reviewed and worked in depth using scientific and commercial software		
<ol style="list-style-type: none"> 1. Basics on computers (hardware, software, memory, finite precision) 2. Introduction to computer modeling. 3. Academic test cases of finite differences, finite volume, finite elements and boundary elements. 4. Preprocessing: structured and unstructured mesh methods. 5. Discretization errors and adaptivity. 6. Introduction to 3D computations. 		
Intended Learning outcomes: to demonstrate		
a knowledge and understanding of:	practical hands-on use of computers to solve finite difference, finite volume finite element and boundary element problems; basic preprocessing issues.	
an ability to: (thinking skills)	understand and identify key features to be considered when performing computational simulations of simple engineering problems.	
an ability to: (practical skills)	solve simple academic test cases for all the different numerical techniques for PDEs; develop practical skills related to use of simple academic codes as well as using a commercial code; analyze and assess the output of computational simulations; write report ranging from the definition of the problem at hand to the analysis of the results; public presentation of a complete simulation.	
an ability to: (key skills)	work as team member; produce work to a deadline; write and present work clearly, within a given time and in accordance with the level of understanding of the audience; study independently; use library resources; manage working time.	
Assessment: 30% individual projects, 50% group project, 20% oral examination.		
Recommended texts:		

1st Term Elective Modules

University of Wales Swansea

Modules	ECTS
Advanced Fluid Mechanics	5
Advanced Computational Techniques	5
Communication Skills for Research Engineers	(5) ³

BASIC PROGRAMMING FOR ENGINEERS AND SCIENTISTS		
Credits: 3 Term: 1 Compulsory: NO		
Format :	Lectures	8h
	Examples	13h
	Private study	54h
Lecturers: J. Sarrate, X. Roca		
Contents:		
<p>The purpose of this module is to introduce the basis of the scientific programming. These fundamental programming skills will be acquired using MATLAB. However, the basic concepts may be extended to any other high level programming language. At the end of the module graduates have acquired elementary programming skills in a high-level programming language. Moreover, they have learned to write computer programs that allow them to implement the algorithms needed to solve problems in their own area of science or engineering.</p> <ol style="list-style-type: none"> 1. Introduction to MATLAB: components and environment. 2. Numbers, variables, operators and functions 3. Arrays and matrices 4. Plotting curves and surfaces 5. Loops and decisions 6. Simple input/output facilities 7. Advanced topics: MATLAB tools and profiling 		
Intended Learning outcomes: to demonstrate		
A knowledge and understanding of:	The key issues of object-oriented programming in scientific and engineering applications; C++ language features to implement object-oriented concepts; the advanced and modern techniques of code improvement and optimization.	
an ability to: (thinking skills)	Develop an structured programming approach to solve scientific problems; recognize the MATLAB features that allow to implement a given algorithm..	
an ability to: (practical skills)	implement and develop MATLAB codes to solve problems in a scientific or engineering environment; generate a graphic representation of a given set of data; optimize the performance of an existing MATLAB code using the profiler.	
an ability to: (key skills)	study independently; use library resources; use computational resources, submit the projects in time; produce project reports and present them.	
Assessment: 100% continuous assessment assignments. Practical Work: Exercises will be set, which will involve coding and analyzing some of the presented programming techniques.		
Recommended texts: Lecture notes Recktenwald, G. W., <i>Numerical Methods with MATLAB: implementations and applications</i> , Prentice Hall, 2000. Nakamura S. <i>Numerical analysis and graphic visualization with MATLAB</i> , Prentice Hall, 1996.		

PRE AND POST PROCESSING TECHNIQUES IN COMPUTATIONAL MECHANICS		
Credits: 4 Term: 1 Compulsory: NO		
Format :	Lectures	14h
	Examples	14h
	Private study	68h
Lecturers: J. Sarrate, G. Bugada, M. Riera, X. Roca, M. Escolano		
Contents:		
<p>This module presents an introduction to the first and last step of a numerical simulation in computational mechanics. That is, it presents the numerical techniques involved in the pre and post processing steps. On one hand, the principal techniques that allow building a computational mesh from a CAD model are presented. On the other hand, numerical techniques for the visualization of discrete fields defined on a computational grid are discussed. These techniques are introduced solving practical applications using Gid (an existing commercial package).</p> <ol style="list-style-type: none"> 1. Geometry representation 2. Meshing algorithms overview 3. Structured mesh generation 4. Triangular and tetrahedral mesh generation 5. Quadrilateral and hexahedral mesh generation 6. Mesh quality improvement 7. Fundamentals of scientific visualization 8. Techniques for discrete field representation 		
Intended Learning outcomes: to demonstrate		
a knowledge and understanding of:	the basic steps of the mesh generation process; the advantages and drawbacks of the most used mesh generation algorithms; the fundamentals of scientific visualization.	
an ability to: (thinking skills)	identify several source of problems of a given CAD representation; set up the model attributes to build a mesh; select the proper visualization technique for the corresponding result.	
an ability to: (practical skills)	to generate a finite element model from a CAD model using several GiD; to visualize the numerical results of a finite element simulation using GiD.	
an ability to: (key skills)	study independently; use library resources; submit the projects in time; produce project reports and present them.	
<p>Assessment: 100% continuous assessment assignments. Practical Work: Exercises will be set, which will involve coding some of the presented techniques and using several commercial packages.</p>		
<p>Recommended texts: Lecture notes Further readings Faux D. and Pratt M.J. <i>Computational Geometry for Design and Manufacture</i>, Elli Horwood Publishers, 1987. Thompson J.F., Soni B.K., and Weatherill N.P, <i>Handbook of Grid Generation</i>, CRC press, 1999 Schroeder W., Martin K., Lorensen B., <i>The Visualization Toolkit An Object-Oriented Approach To 3D Graphics</i>, Kitware, Inc, 2002</p>		

NONLINEAR CONTINUUM MECHANICS		
Credits: 5 Term: 1 Compulsory: NO		
Format :	Lectures	20h
	Examples	10h
	Private study	95h
Lecturers: J. Bonet		
Contents:		
<ol style="list-style-type: none"> 1. Introduction: Categories of nonlinear continuum and structural analysis, Simple beam and column examples, Alternative strain measures, Simple truss example, Introduction to solution process, Mathematical preliminaries; vectors, tensors, directional derivative, linearization, Newton-Raphson solution. 2. Kinematics: Material and spatial descriptions of motion, Deformation gradient and strain tensors, Polar decomposition, Volume and area relations, Velocity gradient and rate of deformation tensors. 3. Stress and Equilibrium: Cauchy stress tensor, Spatial equilibrium and virtual velocity equations, Work conjugacy and alternative expressions of equilibrium, Alternative stress tensors. 4. Constitutive Equations: Hyperelasticity, elasticity tensor, isotropic elasticity 5. Linearized Equilibrium Equations: Newton-Raphson re-visited, Linearized spatial equilibrium equations, [Equilibrium & Total Potential Energy] 6. FE Discretization and Solution: Kinematics, Equilibrium, Linearized equilibrium, Newton-Raphson solution. 		
Intended Learning outcomes: to demonstrate		
a knowledge and understanding of:	the fundamentals of finite deformation analysis, why such an analysis is nonlinear and how finite deformation problems can be established and solved numerically using the finite element method.	
an ability to: (thinking skills)	formulate and solve simple geometrically nonlinear problems using the Newton-Raphson method. Undertake exercises illustrating various aspects of geometrically nonlinear kinematics.	
an ability to: (practical skills)	develop practical skills related to modelling of geometrically nonlinear problems. Perform analysis of geometrically nonlinear problems by employing a finite element package.	
an ability to: (key skills)	study independently and use library resources. Effectively take notes and manage working time.	
Assessment: 40% project work, 60% closed book exam (with formula sheet provided).		
Recommended texts:		
Bonet, J. and Wood. R. D. Nonlinear continuum mechanics for finite element analysis, Cambridge Univ. Press, 1997, ISBN 0-521-57272-X.		
Belytschko, T., Wing. L. K. and Moran, B. Nonlinear finite elements for continua and structures, Wiley, 2001, ISBN 0-471-98774-3 (paperback)		
Holzapfel, G. A., Nonlinear solid mechanics- a continuum approach for engineering, Wiley, 2000, ISBN 0-471-82319-8 (paperback).		
Crisfield, M., Nonlinear finite element analysis of solids and structures, Vos. 1 & 2, 1991,1997, Wiley, ISBN 0-471-92956-5, ISBN 0-471-95649-X.		
Malvern, L.E., Introduction to the mechanics of continuous media, Prentice Hall, 1969.		
Spencer, A. J. M., Continuum mechanics, Longman, 1980, (out of print).		

ADVANCED FLUID MECHANICS							
Credits: 5 Term: 1 Compulsory: NO							
Format :	<table> <tr> <td>Lectures</td> <td>20h</td> </tr> <tr> <td>Examples</td> <td>10h</td> </tr> <tr> <td>Private Study</td> <td>95h</td> </tr> </table>	Lectures	20h	Examples	10h	Private Study	95h
Lectures	20h						
Examples	10h						
Private Study	95h						
Lecturer: Paul G. Tucker							
Contents:							
<ol style="list-style-type: none"> 1. Basic Concepts & Revision: Summary of vector analysis: Classical theorems: Greens, Gauss, Stokes - Eulerian/Lagrangian derivatives and Reynolds transport theorem (3hrs) 2. Governing Equations: Continuity equations and conservation laws. Mass, momentum and energy conservation. Equation classification. Boundary conditions. Examples. (2hrs) 3. Ideal Fluids: Incompressible, irrotational potential flow. Streamlines, streamfunction. Examples. 4. Viscous Incompressible Flow: Incompressible Navier-Stokes equations: Couette flow, Poiseuille flow, pipe flow. (10 hrs) 5. Compressible flow features and equations (1 hr) 6. The nature of turbulence (3 hrs) 7. Contrasting analytical, numerical and experimental approaches for solving engineering problems (1hr) 							
Intended Learning outcomes: to demonstrate							
a knowledge and understanding of:	Analytical analysis of fluid flows. Derivation of Fluid Flow Equations (Mass Momentum Energy) Euler to Navier Stokes.						
an ability to: (thinking skills)	Construction and understanding of basic analytical tools and solutions for modelling different classes of flows, (from ideal to viscous flow) and contrasting these with numerical and experimental analysis approaches						
an ability to: (practical skills)	Understand practical implications of different flow types, appreciation of dominant forces and interpretation of solutions.						
an ability to: (key skills)	Study independently and use library resources. Effectively take notes and manage working time.						
Assessment: 30% continuous assessment assignments, 70% from end of Term closed book examination							
Recommended texts: I.G. Currie, Fundamental Mechanics of Fluids, 2nd edition, McGraw Hill International Editions, 1993.							
Further Reading: B. Le Mehaute, An Introduction to Hydrodynamics and Water Waves, Springer-Verlag, 1976.							
A.R. Patterson, A First Course in Fluid Dynamics, Cambridge University Press, 1983.							
A.J.Chorin & J.E. Marsden, A Mathematical Introduction to Fluid Mechanics, Springer-Verlag, 1979.							

RESEARCH PLANNING		
Credits: 5 Term: 1 Compulsory: NO		
Format :	Lectures	23h
	Examples	13h
	Private study	89h
Lecturers:		
Contents:		
<ul style="list-style-type: none"> • Information retrieval and synthesis • Setting goals and defining deliverables • Managing research progress • Delegation of tasks • Cost and resources implications • Gantt charts <p>As well as project planning, this module includes a short course aiming to:</p> <ul style="list-style-type: none"> • Identify and define transferable skills • Provide a rationale for skills via both research evidence and stated employer/sector needs. • Provide the opportunity to identify and practise skills needed by engineers, including: communication skills, group-work and team-work skills, negotiation skills and problem-solving skills. • Offer a self-perception inventory to identify and develop future employability skills. 		
Intended Learning outcomes: to demonstrate		
a knowledge and understanding of:	the planning and management of a research project in an academic environment	
an ability to: (thinking skills)	set goals and objectives, plan means to achieve them and define deliverables	
an ability to: (practical skills)	plan and produce Gantt charts	
an ability to: (key skills)	use information sources, work in teams, negotiate and solve problems	
Assessment: Continuous assessment		
Recommended texts: Resource packs from lecturer		

2nd Term Modules

Universitat Politècnica de Catalunya/CIMNE

Compulsory modules	Total ECTS	Solids Mechanics ECTS	Fluid Mechanics ECTS
Computational solid mechanics	4	4	
Finite elements in fluids	4		4
Computational structural mechanics and dynamics	4	4	
Computational wave propagation	4	1	3
Computer assignment	4	2	2

Elective modules (subject to timetable constrains and availability)

to be chosen as to complete at least 15 ECTS in a specialization

Seminar series in Computational Engineering and Applied Sciences	3	2	2
Advanced discretization methods	3	2	2
Optimization	2	2	2
Verification and Validation	2	2	2
Coupled problems	2	1	1
Computational contact mechanics	2	2	
Multiscale computational mechanics	2	2	
Computational material failure	2	2	
Computational geomechanics	2	2	
Computational multibody dynamics	2	2	
Fluid-structure interaction in fast transient dynamics	2		2
Mathematical problems for environmental problems	2		2
Computational fluid dynamics	3		3

COMPUTATIONAL SOLID MECHANICS		
Credits: 4 Term: 2 Compulsory: YES		
Format :	Lectures	20h
	Examples	12h
	Private study	78h
Lecturers: J. Oliver		
Contents:		
<p>This module focuses on numerical methods applied to modeling non-linear material behaviour in solids. Emphasis is done in the integration of the constitutive models and the insertion of material non-linearity in finite element settings. The presentation covers both the essential theoretical aspects as well as hands-on applications.</p> <ol style="list-style-type: none"> 1. Constitutive modeling of materials 2. Elasticity and visco-elasticity 3. Continuum damage and visco-damage 4. Plasticity and visco-plasticity 5. Material stability 6. Computational techniques in non-linear material modeling of solids. 7. Advanced topics: contact mechanics and extension to finite strains. 		
Intended Learning outcomes: to demonstrate		
A knowledge and understanding of:	the fundamentals of the behaviour of engineering materials and their numerical modeling.	
an ability to: (thinking skills)	understand and identify the key issues relevant to material modeling: identification of the dissipation mechanisms associated to each non-linear behaviour; set up the physically meaningful values for the material properties; identify the proper numerical methods for solving the solids mechanics problem.	
an ability to: (practical skills)	implement and use computer programs to solve solid mechanics problems accounting for material non-linearity; use any one programming language to develop computer codes; use mesh generators to produce appropriate meshes for analysis; use post-processing software and produce graphical representation of results.	
an ability to: (key skills)	study independently; use library resources; submit the projects in time; produce project reports and present them.	
<p>Assessment: 50% continuous assessment assignments, 50% from end of Term examination (50% open-book). Practical Work: Exercises will be set, which will involve coding some of the presented methods.</p>		
Recommended texts:		
Belytschko T., Liu W.K., Moran B., <i>Non-linear Finite Elements for Continua and Structures</i> , Wiley, 2002 Simo J.C, Hughes T.J.R., <i>Computational Inelasticity</i> , Springer, 1997		

FINITE ELEMENTS IN FLUIDS		
Credits: 4 Term: 2 Compulsory: YES		
Format :	Lectures	20h
	Examples	12h
	Private study	78h
Lecturers: A. Huerta, R. Codina		
Contents:		
<p>This module presents the fundamentals of finite element methods in flow problems. Emphasis is given to stabilized methods and time integration. The presentation covers both the essential theoretical aspects as well as hands-on applications. In particular, specific techniques for Euler and Navier-Stokes flows are presented and discussed.</p> <ol style="list-style-type: none"> 1. Conservation equations 2. Stabilization of the steady convection equation 3. Time integration of the unsteady transport equation 4. Compressible flow 5. Unsteady convection-diffusion problems 6. Viscous incompressible flows 7. Modeling turbulence 8. Advanced topics 		
Intended Learning outcomes: to demonstrate		
a knowledge and understanding of:	the fundamentals of the behaviour and numerical approximation of the fluid dynamics equations; spatial and temporal discretizations and relevant mathematical aspects; stabilization of convection and incompressibility.	
an ability to: (thinking skills)	understand and identify the key issues relevant to discretization both in space and time; set up appropriate initial and boundary conditions; identify the proper methods for the corresponding problem.	
an ability to: (practical skills)	implement and use computer programs to solve fluid dynamics problems; use any one programming language to develop computer codes; use mesh generators to produce appropriate meshes for analysis; use post-processing software and produce graphical representation of results	
an ability to: (key skills)	study independently; use library resources; submit the projects in time; produce project reports and present them.	
<p>Assessment: 50% continuous assessment assignments, 50% from end of Term examination (50% open-book). Practical Work: Exercises will be set, which will involve coding some of the presented methods.</p>		
Recommended texts: Lecture notes		
Donea, J., Huerta, A., <i>Finite Element Methods for Flow Problems</i> , Wiley, 2003		

COMPUTATIONAL STRUCTURAL MECHANICS AND DYNAMICS		
Credits: 4 Term: 2 Compulsory: YES		
Format :	Lectures	20h
	Examples	12h
	Private study	78h
Lecturers: M. Cervera, E. Oñate, A. Barbat, F. Zárate		
Contents:		
<p>This module presents the concepts, formulations and applications of the finite element method for analysis of structures with classical and new materials (composites) under static and dynamic loading. The focus is on linear problems, although a brief introduction to non linear structural analysis is also given. The different methods cover the most common structural typologies found in engineering practice, such as dams, tunnels, tanks, shells, buildings, bridges, mechanical components, sheet metal parts, etc.</p> <p>Details of the FEM formulation are given in each case together with a description of the key computational aspects, aiming to introduce students to the programming of the FEM for structural analysis.</p> <p>The module lectures are complemented with hands-on applications of the FEM to the analysis of a wide range of structures.</p> <ol style="list-style-type: none"> 1. Basic concepts of matrix analysis of bar structures. 2. 2D solids. 3. Axisymmetric solid 4. Three dimensional solids. 5. Beams. 6. Thick and thin plates. 7. Folded plate and curved shells 8. Axisymmetric shells 9. Structural dynamics analysis. 10. Introduction to non linear structural analysis 11. Miscellaneous topics 		
Intended Learning outcomes: to demonstrate		
A knowledge and understanding of:	The fundamental of the theory and practice of finite element method for analysis of structures under static and dynamic loading; the basic theoretical aspects for the analysis of each structure; the computational aspects involved in the structural analysis.	
an ability to: (thinking skills)	identify the appropriate finite element theory for the analysis of a particular structure; select the correct FEM solution strategy; have a critical appraisal of the numerical results	
an ability to: (practical skills)	be able to analyze most structural types found in practice using the FEM; be able to use commercial FEM codes for structural analysis; be able to develop a basic FEM code for structural analysis	
an ability to: (key skills)	study structural analysis independently; use library resources; solve structural analysis problems in personal computers; do some basic programming of FEM for structural analysis; be able to pursue advanced modules in structural analysis; effectively managing working time	
Assessment: 70% from end of Term examination (50% open book), 30% by course work		
Recommended texts: Lecture notes		
Further readings: O.C. Zienkiewicz and R.L. Taylor. <i>The finite element method</i> . Vols. 1 and 2, 5 th Edition, Butterworth-Heinemann, 2003.		

COMPUTATIONAL WAVE PROPAGATION		
Credits: 4 Term: 2 Compulsory: YES		
Format :	Lectures	20h
	Examples	12h
	Private study	78h
Lecturers: I. Arias, S. Fernandez-Mendez, J. Mora		
Contents:		
This module introduces basic concepts of wave theory and focuses on computational strategies to simulate the propagation of linear waves in the context of various engineering applications.		
Basic Theory:		
<ol style="list-style-type: none"> 1. Sample physical origins of wave motion: sound in pipe, elastic rod, blood flow 2. Introduction to wave propagation via 1D problems. 3. Elastodynamic theory in 3D. 4. Integral representations and integral equations. 5. Electromagnetics. 6. Acoustics and vibroacoustics. 7. Characteristics and Riemann problems for linear hyperbolic equations 		
Numerical methods for wave propagation:		
<ol style="list-style-type: none"> 8. Boundary Element Method (BEM). 9. Domain based methods: Finite Differences, Finite Volumes and Discontinuous Galerkin: <ol style="list-style-type: none"> a. General formulation for conservation laws b. Numerical flux: upwind methods, Godunov's and Roe's methods c. High-resolution methods: Flux and TVD limiters d. Convergence, accuracy and stability 10. Boundary conditions on artificial boundaries 		
Intended Learning outcomes: to demonstrate		
a knowledge and understanding of:	the fundamentals of the behaviour and numerical approximation of wave propagation problems; basic concepts of wave theory; overview of computational strategies to simulate the propagation of waves.	
an ability to: (thinking skills)	understand and identify the key issues relevant to the discretization of wave propagation problems; identify the appropriate solution methods for each type of problem.;	
an ability to: (practical skills)	implement and use computer programs to solve wave propagation problems; implement and use different solution methods; critically analyze the results of computer programs.	
an ability to: (key skills)	study independently; use library resources; submit the projects in time; produce project reports and present them.	
Assessment: 50% continuous assessment assignments, 50% from end of Term examination (50% open-book).		
Practical Work: Exercises will be set, which will involve coding some of the presented methods.		
Recommended texts: Lecture notes		
Further readings R.J. LeVeque, <i>Finite volume methods for hyperbolic problems</i> , Cambridge Univ. Press, 2002		
A. Taflove, <i>Computational electrodynamics: The finite-difference time-domain method</i> , Artech House, 1995		
J. D. Achenbach, <i>Wave propagation in elastic solids</i> , North Holland Publ. Co., 1973.		
J. Domínguez, <i>Boundary elements in dynamics</i> , Computational Mechanics Publications, Elsevier, , UK, 1993.		
Jianming Jin, <i>The finite element method in electromagnetics</i> , John Wiley & Sons, 1993		

COMPUTER ASSIGNMENT		
Credits: 4 Term: 2 Compulsory: YES		
Format :	Lectures	8h
	Computer laboratory	16h
	Private study	86h
Lecturers:		
Contents:		
Tutored weekly class where case studies and practical examples are reproduced by the students. Topics covered by the other modules are reviewed and worked in depth using scientific and commercial software		
<ol style="list-style-type: none"> 1. Computational plasticity. 2. Structural test cases. 3. Fluid modeling. 4. Wave propagation problems. 5. Dynamics. 6. Real case applications. 		
Intended Learning outcomes: to demonstrate		
a knowledge and understanding of:	practical hands-on use of computers to solve solid and fluid mechanics problems.	
an ability to: (thinking skills)	understand and identify key features to be considered when performing computational simulations of engineering problems.	
an ability to: (practical skills)	solve simple engineering test cases; develop practical skills related to use of computer codes; analyze and assess the output of computational simulations; write report ranging from the definition of the problem at hand to the analysis of the results; public presentation of a complete simulation.	
an ability to: (key skills)	work as team member; produce work to a deadline; write and present work clearly, within a given time and in accordance with the level of understanding of the audience; study independently; use library resources; manage working time.	
Assessment: 30% individual projects, 50% group project, 20% oral examination.		
Recommended texts:		

ADVANCED DISCRETIZATION METHODS		
Credits: 3 Term: 2 Compulsory: NO		
Format :	Lectures	15h
	Examples	9h
	Private study	59h
Lecturers: A. Huerta, E. Oñate, S. Fernandez-Mendez, S. Idelsohn		
Contents:		
<p>This module is an extension of the basic concepts included in compulsory modules “Advanced discretization methods” and “Finite Element method”. Advanced topics of modern numerical techniques for partial differential equations are presented, with application to a wide variety of problems in science, engineering, and other fields. Topics include advanced Finite Elements (Discontinuous Galerkin, level sets, X-FEM) and mesh-free methods.</p> <p>Advanced Finite Elements:</p> <ol style="list-style-type: none"> 1. Discontinuous Galerkin (DG) for hiperbolic problems. Riemann solvers and numerical fluxes. 2. DG for elliptic operators. 3. Extended finite elements (X-FEM) and applications (crack simulation, holes and inclusions, material interfaces) 4. Level sets. <p>Mesh-free methods:</p> <ol style="list-style-type: none"> 8. Overview of mesh-free methods. 9. Moving least squares approximation. 10. Element-free Galerkin method. 11. Smooth particle hydrodynamics. 12. Implementation of essential boundary conditions. 13. Coupling of finite elements and mesh-free methods. 14. Particle finite element methods <p>Discrete element methods</p> <ol style="list-style-type: none"> 15. Overview of method and applications. 16. Basic formulation. 		
Intended Learning outcomes: to demonstrate		
A knowledge and understanding of:	modern numerical techniques for the discretization of boundary value problems and its range of applicability	
an ability to: (thinking skills)	understand and formulate efficient numerical procedures and solve illustrative problems; identify the proper methods for the corresponding boundary value problem.	
an ability to: (practical skills)	understand practical implications of behaviour of numerical methods and solutions; logically formulate numerical methods for solution by computer with a programming language	
an ability to: (key skills)	study independently; use library resources; use a personal computer for basic programming; effectively take notes and manage working time.	
<p>Assessment: 50% continuous assessment assignments, 50% from end of Term examination (50% open-book).</p> <p>Practical Work: Exercises will be set, which will involve coding some of the presented methods.</p>		
<p>Recommended texts: Lecture notes Erwin Stein, René De Borst and Thomas J.R. Hughes (Editors), <i>Encyclopedia of Computational Mechanics</i>, Wiley, 2004 (Volume 1 Chapter 10, Volume 3 Chapter 4) S. Mohammadi, <i>Discontinuum Mechanics Using Finite and Discrete Elements</i>, WITPress, Southampton, 2003</p>		

OPTIMIZATION		
Credits: 2 Term: 2 Compulsory: NO		
Format :	Lectures	10h
	Examples	6h
	Private study	34h
Lecturers: G. Bugeda		
Contents:		
<p>A full comprehensive module on optimization methods for engineering with an in-depth review of the fundamental concept on optimization including gradient-based method, evolutionary-type algorithms, multi-objective optimization, robust optimization procedures, inverse problems and control, etc. The applications cover a wide range of optimization problems in engineering such as shape optimization, process optimization, parameter identification, material optimization, optimal control problems, etc.</p> <ol style="list-style-type: none"> 1. Basic concepts of optimization. 2. Gradient-based methods. 3. Evolutionary algorithms. 4. Multi objective optimization. 5. Robust optimization methods. 6. Inverse problems. 7. Multidisciplinary optimization problems. 8. Programming aspects 9. Applications. 		
Intended Learning outcomes: to demonstrate		
A knowledge and understanding of:	fundamentals of optimization methods for solving a variety of problems in engineering	
an ability to: (thinking skills)	understand different theoretical and computational aspects of a wide range of optimization methods; realize the possibilities offered by the different optimization methods	
an ability to: (practical skills)	develop skills in the practical applications of the different optimization methods and in the problems encountered in the computer implementation of each procedure	
an ability to: (key skills)	study independently; use library resources; effectively take notes and manage work time; be able to follow advanced modules on optimization	
Assessment: 70% from end of Term examination (50% open book), 30% by course work		
Recommended texts: Lecture notes		
Further readings		
Choi, Kyung K., Kim, Nam-Ho, <i>Structural Sensitivity Analysis and Optimization 1. Linear Systems</i> , Springer, 2005		
A. J. Morris, <i>Foundations of Structural Optimization. A Unified Approach</i> , John Wiley & Sons, 1982.		
Fletcher, R., <i>Practical Methods of Optimization</i> , John Wiley & Sons, 1987.		

COUPLED PROBLEMS		
Credits: 2 Term: 2 Compulsory: NO		
Format :	Lectures	10h
	Examples	6h
	Private study	34h
Lecturers: M. Cervera, E. Oñate, M. Chiumenti		
Contents:		
<p>A comprehensive module covering the theoretical and computational aspects in the solution of coupled problems using the finite element method and related discretization procedures. Emphasis is put in the description of the mathematic formulation of each coupled problem and in the details of the practical FEM solution.</p> <ol style="list-style-type: none"> 1. Overview and classification of coupled problems. 2. Fluid-structure interaction. 3. Soil-pore fluid interaction. 4. Thermo-mechanical coupling. 5. Electro-magneto-dynamic coupling. 6. Partitioned and staggered schemes. 7. Programming aspects. 8. Applications. 		
Intended Learning outcomes: to demonstrate		
A knowledge and understanding of:	fundamentals of the solution of a wide range of coupled problems using finite element-type methods	
an ability to: (thinking skills)	understand the difference between the different classes of coupled problems and the theoretical and practical implications of the related FEM solution procedures; be able to formulate a FEM solution procedure for new coupled problems	
an ability to: (practical skills)	develop skills in the practical solution of coupled problems via the FEM; be able to choose the best solution method for each particular coupled problem; get experience in the solution of different coupled problems of practical interest in engineering practice	
an ability to: (key skills)	study independently; use library resources; effective take notes and manage work time; be able to follow advanced modules on coupled problems	
Assessment: 70% from end of Term examination (50% open book), 30% by course work		
Recommended texts: Lecture notes		
Further readings: O.C. Zienkiewicz and R.L. Taylor. <i>The finite element method. Vols. 1, 2 and 3.</i> 5 th Edition, Butterworth-Heinemann, 2003.		

COMPUTATIONAL MULTIBODY DYNAMICS		
Credits: 2 Term: 2 Compulsory: NO		
Format :	Lectures	10h
	Examples	6h
	Private study	34h
Lecturers: E. Oñate, J. Miquel		
Contents:		
<p>A full comprehensive module on computational multibody dynamics for engineers with an in-depth review of fundamental concepts including kinematics description, variational formulation and numerical solution schemes.</p> <ol style="list-style-type: none"> 1. Introduction to multibody dynamics. 2. Kinematics and equilibrium equations. 3. Variational formulation. 4. Finite element discretization. 5. Time integration schemes. 6. Coupled multibody dynamic problems. 7. Computational and programming aspects. 8. Contact problems in multibody dynamics 9. Practical applications. 		
Intended Learning outcomes: to demonstrate		
A knowledge and understanding of:	fundamental of computational multibody dynamics using the FEM with application to engineering problems	
an ability to: (thinking skills)	understand the difference between the different classes of computational multibody dynamics problems and the theoretical and practical implication of the related FEM algorithms; be able to formulate a solution procedure for new computational multibody dynamics problems	
an ability to: (practical skills)	develop skills in the practical solution of computational multibody dynamics via the FEM; be able to choose the best solution method for each particular computational multibody dynamics problems; get experience in the solution of different computational multibody dynamics of practical interest in engineering practice.	
an ability to: (key skills)	study independently; use library resources; effectively take notes and manage work time; be able to follow advanced modules on computational multibody dynamics	
Assessment: 70% from end of Term examination (50% open book), 30% by course work		
Recommended texts: Lecture notes		
Further readings: M. Geradin and A. Cardona. <i>Introduction to multibody dynamics</i> .		

COMPUTATIONAL CONTACT MECHANICS		
Credits: 2 Term: 2 Compulsory: NO		
Format :	Lectures	10h
	Examples	6h
	Private study	34h
Lecturers: C. Agelet de Saracibar, M. Chiumenti		
Contents:		
<p>A fully comprehensive module on computational contact mechanics for engineers with an in-depth review of fundamental concepts including contact kinematics, contact search algorithms, contact consistent tangent operators, contact solution algorithms and others. The module lectures includes examples of applications of the FEM solution of practical problems in contact mechanics of engineering interest such as impact and crash-worthiness problem, multi-body dynamics, metal forming processes, coupled problems, etc.</p> <ol style="list-style-type: none"> 1. Introduction to contact mechanics. 2. Contact kinematics. 3. Contact search algorithms. 4. Finite element formulation. 5. Contact tangent operators. 6. Computational strategy. 7. Contact mechanics problems. 8. Coupled problems. 9. Computational and programming issues. 10. Practical applications. 		
Intended Learning outcomes: to demonstrate		
A knowledge and understanding of:	fundamental of computational contact mechanics for the solution of practical engineering problems using the FEM and related discretization procedures.	
an ability to: (thinking skills)	understand the different aspects in the finite element solution of contact mechanics problems; realize the difficulties and advantages associated to each particular solution scheme	
an ability to: (practical skills)	develop skills in the practical solution of contact mechanics problems using the FEM; be able to choose the best method to solve specific contact mechanics problems	
an ability to: (key skills)	study independently; use library resources; effectively take notes and manage work time; be able to follow advanced modules on contact mechanics	
Assessment: 70% from end of Term examination (50% open book), 30% by course work		
Recommended texts: Module lectures		
Further readings		
T.A. Laursen, " <i>Computational Contact and Impact Mechanics</i> ", Springer, 2002		
P. Wriggers, " <i>Computational Contact Mechanics</i> ", Wiley, 2002		

VERIFICATION AND VALIDATION		
Credits: 2 Term: 2 Compulsory: NO		
Format :	Lectures	10h
	Examples	6h
	Private study	34h
Lecturers: P. Diez, I Arias, N. Pares		
Contents:		
<p>Verification and Validation in Computational Mechanics means controlling the quality of the numerical solution, both related with the discretization and the physical model. The concept of Verification addresses the issue of the accuracy in the numerical solution of the mathematical problem. Complementarily, Validation is associated with the correctness of the equation with respect to the physical reality. The aim of the module is to present these techniques and the comprehensive philosophy of Adaptive Modeling. Adapting the mesh is part of Verification and adapting the model is part of Validation. The first part of the module focuses on error estimation techniques and mesh adaptation. Error estimators are classified and discussed, both for assessing the energy norm of the error and for any arbitrary quantity of interest. Then, the application of similar tools to assess the quality of the models and to possibly adapt them is presented in the second part of the module.</p>		
Intended Learning outcomes: to demonstrate		
a knowledge and understanding of:	the fundamentals of error estimation and adaptivity; its classification and the available methods; the use of these techniques in adaptive procedures leading to optimal meshes.	
an ability to: (thinking skills)	understand the design loop as a trial and error process where the numerical simulation must be reliable to properly replace experiments; account for the proper tools that may certify the quality of the numerical simulations and to guarantee that the design is safe; realize that Computational Mechanics provides approximate solutions, as accurate as the user wishes and it is able to pay.	
an ability to: (practical skills)	implement and use computer programs to estimate error and improve (adapt) meshes and models.	
an ability to: (key skills)	study independently; use library resources; submit the projects in time; produce project reports and present them.	
<p>Assessment: 50% continuous assessment assignments, 50% from end of Term examination (50% open-book). Practical Work: Exercises will be set, which will involve coding some of the presented methods.</p>		
<p>Recommended texts: Lecture notes Ainsworth, Oden, <i>A posteriori Error Estimation in Finite Element Analysis</i>, Wiley 2000.</p>		

MULTISCALE COMPUTATIONAL MECHANICS		
Credits: 2 Term: 2 Compulsory: NO		
Format :	Lectures	10h
	Examples	6h
	Private study	34h
Lecturers: M. Arroyo, A. Rodriguez-Ferran		
Contents:		
<p>This module will focus on computational solid mechanics with full nonlinear kinematics. For the sake of clarity, the main emphasis will be on hyperelastostatics, although the framework for general constitutive relations and hints on finite deformation inelasticity will be provided. An introduction to the microstructural and atomistic foundations of constitutive theory will be presented, as well as an overview of modern multi-scale approaches to material modeling. The duality of finite deformation solid mechanics and shape and microstructure optimization through the theory of the material or configurational equilibrium will be presented to broaden the scope of the module. In addition to quasistatic equilibrium problems, the module will provide a brief account on time integration in finite kinematics solid dynamics.</p>		
Intended Learning outcomes: to demonstrate		
A knowledge and understanding of:	the formulation and discretization of solid mechanics problems with full nonlinear kinematics, and the solution of the resulting equations; basic constitutive theory, as well as micro-structure and physical foundations;	
an ability to: (thinking skills)	understand physically and mathematically finite deformation elasticity and its discretization; make the connection with optimization; understand the physical underpinnings of constitutive theory to critically use constitutive models.	
an ability to: (practical skills)	implement and use computer programs to solve nonlinear solid mechanics problems; use and implement different solution methods and constitutive models; critically analyze the results of computer programs.	
an ability to: (key skills)	study independently; use library resources; submit the projects in time; produce project reports and present them.	
<p>Assessment: 50% continuous assessment assignments, 50% from end of Term examination (50% open-book). Practical Work: Exercises will be set, which will involve coding some of the presented methods.</p>		
<p>Recommended texts: Lecture notes Bonet, Wood, <i>Nonlinear Continuum Mechanics for Finite Element Analysis</i>, Cambridge, 1997 Belytschko, Liu, Moran, <i>Nonlinear Finite Elements for Continua and Structures</i>, Wiley 2000</p>		

FLUID-STRUCTURE INTERACTION IN FAST TRANSIENT DYNAMICS		
Credits: 2 Term: 2 Compulsory: NO		
Format :	Lectures	10h
	Examples	10h
	Private study	30h
Lecturers: F. Casadei, Y. Vidal		
Contents:		
<p>The objective of the Module is to provide participants with a good understanding of state-of-the-art techniques for the numerical simulation of fast transient dynamic phenomena, which occur in many safety-related applications. These are typically explosions, crashes, impacts, etc., both due to natural phenomena and to malicious actions such as terrorist attacks. The Module focuses on coupling between fluid and structural domains. An important part of the Module is represented by the practical exercises. These will mainly be hands-on interactive computer sessions, in which the participants will use the EUROPLEXUS code (developed jointly by JRC and CEA and distributed by Samtech S.A.) to solve both some academic problems, in order to consolidate the theoretical knowledge, and some typical medium-sized applications.</p> <ol style="list-style-type: none"> 7. Introduction examples to FSI problems 8. Overview of modeling the structural domain and treatment of essential boundary conditions 9. ALE formulation and modeling of the fluid domain 40. Mesh rezoning algorithms and free surface modeling 51. ALE fluid-structure interaction 62. Advanced topics and applications: <ol style="list-style-type: none"> a. ALE description of structures b. Non-conforming FSI c. Lagrangian contact d. Spectral elements e. Domain decomposition 		
Intended Learning outcomes: to demonstrate		
a knowledge and understanding of:	the fundamentals of fluid-structure interaction; state-of-the-art techniques for the numerical simulation of fast transient dynamic phenomena; ALE formulation.	
an ability to: (thinking skills)	identify the key issues when performing explicit fast-transient dynamic analysis in fluid-structure interaction.	
an ability to: (practical skills)	set a model and use the appropriate formulation for a given problem; use the EUROPLEXUS code in practical application examples.	
an ability to: (key skills)	study independently; use EUROPLEXUS as a commercial code for fluid-structure interaction; effectively take notes and manage working time.	
Assessment: continuous assessment assignments.		
Recommended texts: Lecture notes		

COMPUTATIONAL FLUIDS DYNAMICS		
Credits: 2 Term: 2 Compulsory: NO		
Format :	Lectures	10h
	Examples	6h
	Private study	34h
Lecturers: A. Huerta, R. Codina, S. Fernandez-Mendez		
Contents:		
<ol style="list-style-type: none"> 1. The basic equations in fluid dynamics (Navier-Stokes, Gas dynamics and Euler equations, potential flow) 2. The numerical computation of potential flows 3. Nonlinear scalar conservation laws 4. Finite volumes for nonlinear conservation laws 5. Nonlinear systems of conservation laws (in particular Euler equations) 6. Finite volumes for nonlinear systems 7. Turbulence 8. Advanced topics 		
Intended Learning outcomes: to demonstrate		
a knowledge and understanding of:	fluids dynamics equations; conservative schemes; key issues in turbulence modelling.	
an ability to: (thinking skills)	understand numerical procedures and solve illustrative problems; identify the proper methods for the corresponding problems, this includes identifying appropriate boundary conditions.	
an ability to: (practical skills)	understand practical implications of behaviour of numerical methods and solutions; use commercial CFD codes.	
an ability to: (key skills)	study independently; use library resources; effectively take notes and manage working time.	
Assessment: 100% continuous assessment assignments. Practical Work: Exercises will be set, which will involve perform CFD applications.		
Recommended texts: Lecture notes		

MATHEMATICAL MODELING OF ENVIRONMENTAL PROBLEMS		
Credits: 2 Term: 2 Compulsory: NO		
Format :	Lectures	8h
	Examples	8h
	Private study	34h
Lecturers: A. Perez-Foguet		
Contents:		
<p>This module presents the fundamentals of physical and mathematical modelling in environmental problems, groundwater and atmospheric pollution, transport, diffusion and adsorption-desorption processes. Emphasis is given to the modelling through ordinary and partial differential equations, and specifically to the dimensionless analysis of the mathematical models and the adaptive modelling simulation in complex problems. The module covers both theoretical aspects as well as hands-on applications.</p> <ol style="list-style-type: none"> 1. Introduction to continuum mechanics problems of environmental interest 2. Incompressible problems 3. Compressible problems 4. Numerical simulations: non-adsorptive media 5. Numerical simulations: adsorptive media 		
Intended Learning outcomes: to demonstrate		
a knowledge and understanding of:	the fundamentals of mathematical and numerical modelling of balance equations; specificity of mathematical modelling of adsorption-desorption media; key issues of numerical simulation of realistic problems of environmental interest.	
an ability to: (thinking skills)	identify the more relevant characteristics of convection-diffusion-reaction equations from a numerical behaviour a point of view; identify the relative importance of physical processes at a certain time scale; identify the proper model for the corresponding accuracy requirements and available data.	
an ability to: (practical skills)	implement and use computer programs to solve continuum mechanics transport problems; produce graphical representation of results	
an ability to: (key skills)	work-group study; use library and ICT resources; produce and submit project reports on time.	
<p>Assessment: 50% continuous assessment assignments, 50% from end of Term examination (50% open-book). Practical Work: Exercises will be set, which will involve coding some of the presented methods.</p>		
<p>Recommended texts: Lecture notes Arya, S., <i>Air Pollution Meteorology and Dispersion</i>, Oxford University Press, 1999. Marchuk, G.I., <i>Mathematical Modeling for the Problems of Environment</i>, 1985. Smoller, J., <i>Shock Waves and Reaction-Diffusion Equations</i>, Springer Verlag, Berlin 1992. Wankat, P.C., <i>Rate Controlled Separations</i>, Blackie Academic and Professional, Glasgow, 1994. Yong, R.N., Mohamed, A.M.O., Warkentin, B.P., <i>Principles of Contaminant Transport in Soils</i>, 1992.</p>		

2nd Term Modules

University of Wales Swansea

30 ECTS to be chosen, at least 15 from one subject specialisation

Structural Engineering

ECTS

Dynamics of Structures	5
Computational Plasticity	5
Advanced Structural Analysis	5
Nonlinear Continuum Mechanics	5

Fluid Mechanics

Computational Fluid Dynamics	5
Fluid Structure Interaction	5
Reservoir Simulation	5
Computational Electromagnetics	5

Other (subject to timetable constraints and availability)

Advanced Structural Analysis	5
Water Systems Supply and Computational Simulation	5
Optimisation	5
Engineering Design Optimisation	5
Computational Intelligence in Engineering	5

DYNAMICS OF STRUCTURES		
Credits: 5 Term: 2 Compulsory: NO		
Format :	Lectures	22h
	Examples	11h
	Private study	92h
Lecturers: Y. Feng		
Contents:		
<ol style="list-style-type: none"> 1. Introduction: Dynamic effects on structure, design issues. [1] 2. Single Degree of Freedom Problems: the SDOF spring-mass system, equivalent SDOF structures – energy method, analytical solution of SDOF problems, step by step solution methods, earthquake loading, response and design spectra, Eurocode- 8 inelastic spectrum. [12] 3. Multiple Degree of Freedom Problems: natural modes and frequencies of vibration, modal decomposition, reduction and iterative methods, earthquake loading, shear building model, design considerations. [6] 4. Distributed Mass Systems: vibration of rods, transversal vibration of beams and plates, 3-D elastic waves, finite element discretization. [2] 5. Revision [1] 		
Intended Learning outcomes: to demonstrate		
a knowledge and understanding of:	Basic dynamic concepts of SDOF systems such as dynamic magnification, resonance, damping. The Rayleigh method for the simplification of complex structures to a SDOF system. Earthquake response and design spectra. Analytical and step-by-step integration methods for impulse and periodic forces. Modes of vibration and modal decomposition. Reduction methods. Mass damping. The shear building simplified model.	
an ability to: (thinking skills)	Determine Rayleigh vibration shape functions for simple structures. Distinguished between stiffness/mass/damping dominated problems. Identify dynamic loading on bridges, footbridges, floors, etc. resulting from moving loads or rhythmic activities. Identify the correct solution process for different loads. Identify correct earthquake design spectrum following Eurocode-8. Identify adequate problem reduction strategies for MDOF problems.	
an ability to: (practical skills)	Evaluate equivalent stiffness, mass parameters and natural frequency of vibration for simple structures using the Rayleigh method. Use Excel spreadsheets to integrate step-by-step SDOF structures under complex loading. Use earthquake design spectra. Tune a mass damper. Use the simple shear building model to evaluate earthquake design forces on simple buildings. Combine peak responses from different modes.	
an ability to: (key skills)	Problem solving. Use a personal computer, in particular Excel. Study independently and use library resources. Effectively take notes and manage working time.	
<p>Assessment: Written, open book, examination (2 hrs) at the end of Term 2 accounts for 75% of the marks, the remainder are awarded to an individual project, for which students are expected to solve a dynamical problem using Excel and write a technical report on their findings. Penalty for late submission of course work is Zero mark in the course work.</p> <p>Practical work: Individual projects allocated during the module.</p>		
<p>Recommended texts: Chopra, Dynamics of Structures, Prentice Hall Clough & Penzien, Dynamics of Structures, McGraw-Hill ICE (Design and Practice Guides), Dynamics - An introduction for Civil & Engineers</p>		

COMPUTATIONAL PLASTICITY		
Credits: 5 Term: 2 Compulsory: NO		
Format :	Lectures	21h
	Examples	15h
	Private study	89h
Lecturers: D. Peric		
Contents:		
<ol style="list-style-type: none"> 1. Introduction: Historical Perspective. Physical Motivation. Rate Independent Plasticity. Rate Dependence. Creep. Rheological Models. [1] 2. 1-D Mathematical Model: Yield Criterion. Flow Rule. Loading / Unloading Conditions. Isotropic and Kinematic Hardening Models. 1-D Elasto-Plastic Boundary Value Problem. [2] 3. Computational Aspects of 1-D Elasto-Plasticity: Integration Algorithms for 1-D Elasto-Plasticity. Operator Split. Return Mapping. Incremental Elasto-Plastic BVP. Consistent Tangent Modulus. [3] 4. Classical Model of Elasto-Plasticity: Physical Motivation. Classical Mathematical Model of Rate-Independent. Elasto-Plasticity: Yield Criterion. Flow Rule. Loading / Unloading Conditions. [2] 5. Computational Aspects of Elasto-Plasticity: Integration Algorithms for Elasto-Plasticity. Operator Split. The Trial Elastic State. Return Mapping. Incremental Elasto-Plastic BVP. Consistent Tangent Modulus. [3] 6. Plane Strain Von Mises Elasto-Plastic Model: Continuum. Integration Algorithm. Operator Split. The Trial Elastic State. Return Mapping; Incremental Elasto-Plastic BVP: Consistent Tangent Modulus. [3] 7. Integration Algorithms for Generalised Elasto-Plasticity: Stress Integration Algorithm. Example: Stress Integration Algorithm for the Barlat Anisotropic Yield Criterion. [2] 8. Computational Aspects of 1-D Large Strain Elasto-Plasticity: 1-D Mathematical Model: Multiplicative Elasto-Plastic Split. Logarithmic Stretches. Hencky's Strain Energy. Yield Criterion. Flow Rule. Isotropic Hardening Model. 1-D Elasto-Plastic BVP. Integration Algorithms for 1-D Large Strain Elasto-Plasticity. Backward Euler. Operator Split. Return Mapping. Exponential Map. Incremental Elasto-Plastic BVP. [3] 9. Generalisations and Applications of Plasticity: Plasticity Theory of Friction. Plasticity in Engineering Practice: Metal Forming. Impact Dynamics and Crashworthiness. Geomechanics. [2] 		
Intended Learning outcomes: to demonstrate		
a knowledge and understanding of:	Fundamentals of computational modelling of inelastic materials with emphasis on rate independent plasticity. A sound basis for approximation methods and finite element method, in particular.	
an ability to: (thinking skills)	Understand different methodologies for discretisation of different time evolution problems, and rate-independent elasto-plasticity in particular.	
an ability to: (practical skills)	Develop practical skills related to modelling of inelastic history dependent materials. Formulate and implement a computational procedure for integration of rate-independent elasto-plasticity in 1-D. Perform analysis of engineering problems in elasto-plasticity by employing a commercial finite element package.	
an ability to: (key skills)	Study independently and use library resources. Develop programming skills and ability to use commercial software. Effectively take notes and manage working time.	
Assessment: 50% by examination (closed book exam), 50% by course work.		
Practical work: Attendance is a requirement. The coursework will consist of three small projects that will require both hand calculation and computer simulations. Computer simulation will require certain amount of programming and use of the existing finite element software package Elfen. The project reports should consist of two parts: (i) a discussion related to general aspects of formulation and computational treatment of the problem under consideration, (ii) description of numerical solution of an individual problem.		
Recommended texts: Lecture Notes		
Further readings: M.A. Crisfield: Basic plasticity Chapter 5. in: Non-linear Finite Element Analysis of Solids and Structures. Volume1: Essentials , John Wiley, Chichester, 1991		
J.Lemaitre and J.-L. Chaboche: Mechanics of Solid Materials , Cambridge University Press, Cambridge, 1990		
J. Lubliner: Plasticity Theory , Macmillan, New York, 1990		
D.R.J.Owen and E.Hinton: Finite Elements in Plasticity: Theory and Practice Pineridge Press, Swansea, 1980		
J. C. Simo and T. J. R. Hughes, Computational Inelasticity, Springer, 1998.		
O.C.Zienkiewicz and R.L.Taylor: Inelastic and non-linear materials, Chapter 3 in The Finite Element Method. Volume 2: Solid Mechanics, 5-th edition, Butterworth-Heinemann, Oxford, 2000.		

ADVANCED STRUCTURAL ANALYSIS		
Credits: 5 Term: 2 Compulsory: YES		
Format :	Lectures	20h
	Examples	10h
	Private study	95h
Lecturers: D. R. J. Owen		
Contents:		
<ol style="list-style-type: none"> 1. Introduction to the flexural behaviour of plates. Equilibrium conditions and the development of the governing equation for plate bending in terms of bending moments. [2] 2. Compatibility conditions. Constitutive laws and the moment/curvature relations. The governing equation in terms of displacements. [2] 3. Boundary conditions for rectangular plates. Navier's solution for simply supported rectangular plates. [2] 4. Point loaded simply supported rectangular plates. Development of the governing equations for axisymmetrically loaded circular plates. [2] 5. Solution of axisymmetrically loaded circular plate problems. Introduction to the limit analysis of reinforced concrete slabs. [2] 6. Principle of virtual work method and equilibrium method for the evaluation of limit loads of slabs. Problem solution involving orthotropically reinforced slabs. [2] 7. Introduction to shell behaviour. The theory of shell action under membrane behaviour. [2] 8. The solution of a range of engineering problems involving axisymmetrically loaded shells of revolution. [2] 9. Theory of unsymmetrically loaded shells of revolution. Solution of engineering examples. [2] 10. Introduction to prestressed concrete. Uniformly prestressed sections – theory and numerical examples. [2] 11. Eccentrically prestressed sections – theory and numerical examples. Statically indeterminate systems. Evaluation of concordant tendon profiles. [2] 12. Revision. [2] 		
Intended Learning outcomes: to demonstrate		
a knowledge and understanding of:	The principles of equilibrium, compatibility and the influence of material behaviour. Virtual Work expressions of equilibrium and compatibility and the Unit Load Theorem.	
an ability to: (thinking skills)	Identify the forces applied by various supports. Distinguish between axial, bending, shear and torsional load carrying actions. Distinguish between statically determinate and indeterminate structures. Identify appropriate methods of analysis for trusses, beams and frames.	
an ability to: (practical skills)	Apply the equations of static equilibrium to calculate reactions, axial forces, bending moments, shear forces and torsional forces. Use the Unit Load Method for the calculation of displacements and rotations in structures. Analyse simple externally indeterminate 2-dimensional structures. Apply the Moment Distribution Method to the analysis of statically indeterminate beams. Use a computer to model and analyse trusses, beams and frames..	
an ability to: (key skills)	Use a personal computer. Study independently and use library resources. Effectively take notes and manage working time.	
Assessment: 100% from end of Term closed book examination.		
Recommended texts: STRUCTURES - theory and analysis by M.S. Williams & J. D. Todd, MACMILLAN Press, 2000, ISBN 0-333-67760-9. (This covers Level 2 and Level 3 material)		
Further reading: Coutie, Coates and Kong, Structural Analysis , 1998, 3rd Edition, VNR. .		

COMPUTATIONAL CASE STUDY (STRUCTURES)		
Credits: 10 Term: 2 Compulsory: YES		
Format :	Tutorials Private study	10h 240h
Lecturers: Individual research supervisor		
Contents:		
<ol style="list-style-type: none"> 1. Literature review on chosen research topic. 2. Familiarisation with chosen research topic. 3. Planning of MSc thesis. 		
Intended Learning outcomes: to demonstrate		
a knowledge and understanding of:	The main aspects and state-of-the-art of the chosen MSc research topic; main problems and necessary steps to move forward in the chosen research topic.	
an ability to: (thinking skills)	Identify key aspects of a research topic.	
an ability to: (practical skills)	Use web-based tools to perform bibliographic searches on a given topic.	
an ability to: (key skills)	Produce work to a deadline. Perform a bibliographic search on a given topic, select essential information for familiarisation with the subject. Plan research in advance.	
Assessment: Written report (5,000 word report on the chosen MSc research topic.) + Oral presentation.		
Recommended texts: To be defined by supervisor according to chosen research topic.		

COMPUTATIONAL FLUID DYNAMICS		
Credits: 5 Term: 2 Compulsory: NO		
Format :	Lectures	20h
	Examples	20h
	Private study	85h
Lecturers: P. Nithiarasu		
Contents:		
<ol style="list-style-type: none"> 1. Introduction to CFD [1] 2. CFD model and applications [1] 3. Navier-Stokes equations [2] 4. Mathematical nature of equations [2] 5. Spatial and temporal discretizations [3] 6. Finite difference and finite volume schemes [3] 7. Finite element schemes [3] 8. Stabilized solution algorithms [2] 9. Turbulence [1] 10. Advanced topics [1] 11. Mini-projects [1] 		
Intended Learning outcomes: to demonstrate		
a knowledge and understanding of:	Fluid dynamics equations, spatial and temporal discretizations and relevant mathematical aspects	
an ability to: (thinking skills)	Identify the key issues relevant to discretization both in space and time. Set up appropriate initial and boundary conditions.	
an ability to: (practical skills)	Implement and use computer programs to solve fluid dynamics problems. Use any one programming language to develop computer codes. Use mesh generators to produce appropriate meshes for analysis. Identify appropriate boundary nodes to implement the boundary conditions. Use post processing soft-wares and produce graphical representation of results	
an ability to: (key skills)	Submit projects in time. Produce project reports.	
Assessment: Written closed-book examination (70%), projects (30%).		
Penalty for late submission of continual assessment assignment: No marks awarded for late submissions.		
Project work: Two projects. One on schemes and another on application.		
Recommended texts: Text: Module notes C. Hirsch, Numerical computation of internal and external flows, Vol 1 and Vol 2, Wiley, 1989. O.C. Zienkiewicz, R. L. Taylor and P. Nithiarasu, The finite element method for fluid dynamics, 6th Edition, Elsevier, 2005. R.W. Lewis, P. Nithiarasu and K.N. Seetharamu, Fundamentals of the finite element method for heat and fluid flow, Wiley, May 2004.		

COMPUTATIONAL CASE STUDY (FLUIDS)		
Credits: 10 Term: 2 Compulsory: YES		
Format :	Tutorials Private study	10h 240h
Lecturers: Individual research supervisor		
Contents:		
<ol style="list-style-type: none"> 1. Literature review on chosen research topic. 2. Familiarisation with chosen research topic. 3. Planning of MSc thesis. 		
Intended Learning outcomes: to demonstrate		
a knowledge and understanding of:	The main aspects and state-of-the-art of the chosen MSc research topic; main problems and necessary steps to move forward in the chosen research topic.	
an ability to: (thinking skills)	Identify key aspects of a research topic.	
an ability to: (practical skills)	Use web-based tools to perform bibliographic searches on a given topic.	
an ability to: (key skills)	Produce work to a deadline. Perform a bibliographic search on a given topic, select essential information for familiarisation with the subject. Plan research in advance.	
Assessment: Written report (5,000 word report on the chosen MSc research topic.) + Oral presentation.		
Recommended texts: To be defined by supervisor according to chosen research topic.		

ADVANCED GEOMECHANICS		
Credits: 5 Term: 2 Compulsory: NO		
Format :	Lectures	22h
	Examples	11h
	Private study	92h
Lecturers: G. N. Pande		
Contents:		
<ol style="list-style-type: none"> 1. Theory of plasticity in soil mechanics. Mohr-Coulomb criterion, flow rule and dilatency, strain hardening, derivation of constitutive matrix for Mohr-Coulomb criterion, draw backs of Mohr Coulomb in undrained finite element analysis of soil masses. Triaxial tests, identification of total and effective stress strength parameters. 2. Critical state soil mechanics – critical state, volumetric and deviatoric hardening, drained and undrained effective stress paths, link between rate of dilation and the strength, derivation of constitutive matrix for the triaxial stress space. Predictions of strength under various stress paths and drainage conditions. 3. Terzaghi's theory of one –dimensional consolidation, use of PLAXIS FE software in the analysis of soil structures. 		
Intended Learning outcomes: to demonstrate		
a knowledge and understanding of:	The relevance of drained and undrained analysis of soil masses. Appreciation of the different mechanical response of loose and dense geomaterials. The basic concepts of theories of soil plasticity and the critical state model for soils.	
an ability to: (thinking skills)	To choose appropriate advanced techniques of geotechnical analysis in solving engineering problems.	
an ability to: (practical skills)	Use finite element software to analyse practical problems in geotechnical engineering.	
an ability to: (key skills)	Work as a member of a team including working to a deadline. Accurately record data. Study independently and use library resources. Effectively take notes and manage working time.	
<p>Assessment: 25% practical project, remaining 70% based on 2hr end of Term closed book examination. Penalty for late submission of assignment is 20% marks/week.</p> <p>Project work: The students are required to solve a geotechnical problem such as analysis of foundations, tunnel or earth embankment using PLAXIS software.</p>		
Recommended texts: Lecture notes supplied.		

COMMUNICATION SKILLS FOR RESEARCH ENGINEERS		
Credits: 5 Term: 2 Compulsory: YES		
Format :	Lectures	15h
	Examples	15h
	Private study	95h
Lecturers: M. Cross		
Contents:		
1. Written Communication: Reports, Theses, Journal & Conference papers [6]		
2. Oral Communication: Research Presentations, Attending conferences & presenting papers. [6]		
3. Role Play: Attending & chairing meetings, Job interviews. [3]		
Intended Learning outcomes: to demonstrate		
a knowledge and understanding of:	Methods of delivery of oral presentations. Logical structure of scientific texts (including standards of referencing).	
an ability to: (thinking skills)	Identify key aspects of research work for preparation of effective research presentations/papers.	
an ability to: (practical skills)	Use computer software to prepare reports/presentations.	
an ability to: (key skills)	Produce work to a deadline. Summarise and organise complex ideas in order to present them clearly within a given time and in accordance with the level of understanding of the audience. Effectively take part in meetings.	
Assessment: Written report (50%), Oral presentation (50%).		
Recommended texts: Module Overheads Set.		

OPTIMISATION		
Credits: 5 Term: 2 Compulsory: NO		
Format :	Lectures	22h
	Examples	5h
	Private study	98h
Lecturers: A P Wardle		
Contents:		
<ol style="list-style-type: none"> 1. Introduction: Statement of the optimisation problem; objective function; design vector; types of constraint; classification of optimisation problem. [2] 2. Linear programming: Two variable graphical structure; Simplex method. [3] 3. One-Dimensional Minimisation Problems: Unrestricted search; dichotomous search; Fibonacci and golden section method; quadratic and cubic functions; Newton's and secant procedures. [6] 4. Multidimensional Minimisation Problems: Random and grid search procedures; use of pattern searches the methods of Powell and Hooke and Jeeves; Rosenbrock's approach; the Simplex pattern procedure. [3] 5. Descent methods: The Hessian; Concavity and convexity; Steepest descent (Cauchy) method; Fletcher-Reeves procedures; Newton's method; Davidon-Fletcher-Powell approach. [4] 6. Constrained Optimisation Techniques: Random search; Reduced gradient method; penalty functions. [4] 		
Intended Learning outcomes: to demonstrate		
a knowledge and understanding of:	The setting-up of typical optimisation problems; the concept of error and the way in which search techniques approach various optima; common methods of determining the optimum of univariable unimodal functions; the use of direct search techniques for finding the optima of multivariable unconstrained functions; the use of indirect search techniques for finding the optima of multivariable constrained functions; the Simplex technique of linear programming; procedures for applying constraints to multivariable systems; the use of search techniques to determine the optima of constrained multivariable systems; proficiency in the critical skills which will enable reasoning, deduction and application of the knowledge base.	
an ability to: (thinking skills)	Identify suitable target variables for an optimisation exercise; formulate cost (objective) functions for a given problem; identify and formulate equality and inequality constraints; use the Dichotomous, Fibonacci and Golden Search methods in determining the optimum of a univariable unimodal function; use interpolation procedures for finding the optimum of a univariable unimodal function; to fit quadratic or cubic functions in order to obtain an approximate optimum; formulate linear programming (LP) problems and solving them using the Simplex method; identify and overcome complications in an LP problem; distinguish between direct and indirect search methods; determine the nature of optima using the Hessian; apply the methods of steepest descent and Newton to a multivariable function; apply Marquadt's procedure for modifying the Hessian; use secant methods for optimising multivariable unconstrained functions; understand multivariable direct search methods; apply constraints to multivariable optimisation problems; use the generalised reduced gradient method for the analysis of multivariable constrained functions.	
an ability to: (practical skills)	Illustrate the approach to an optimum by sketch or graphical means; determine suitable search paths and illustrating them graphically; calculate the optimum of univariable unimodal functions by a variety of methods; estimate the optima of a multivariable function with or without constraints; calculate the optimum solution to a variety of linear programming problems.	
an ability to: (key skills)	Employ the basic concepts of an optimum solution to a given situation; apply procedures of analysis to a process or procedure to derive the optimum case; use information technology in the use of spreadsheets and drawing programs; use data, reasoning through problems and reach probabilistic judgements.	
Assessment: 100% written examination.		
Recommended texts: T F Edgar and D M Himmelblau, Optimisation of Chemical Processes, McGraw-Hill, ISBN 0-07-018991-9.		

ENGINEERING DESIGN OPTIMISATION		
Credits: 5 Term: 2 Compulsory: NO		
Format :	Lectures	18h
	Examples	32h
	Private study	75h
Lecturers: J. Sienz		
Contents:		
<ol style="list-style-type: none"> 1. Overview. Structural optimisation as a) conceptual design tool, b) design improvement tool. Classification of optimisation problems: topology, size, shape, and material. Lessons from Nature. [1] 2. Modelling and formulation of optimisation problems. Analysis vs. design model. Criteria for optimisation, choice of design variables and objective function. Discrete and continuous problems. [2] 3. Optimisation algorithms: gradient based and gradient free methods [1] 4. Topology Optimisation or computational sculpturing: a) homogenisation, b) evolutionary, c) hybrid [2] 5. Shape Optimization: a) gradient based shape optimization, b) adaptive growth, c) growth method, d) morphing. [2] 6. Fully Integrated Design Optimization. CAD, geometric modeling, mesh generation, adaptive finite element analysis, sensitivity analysis, optimisation, image processing. [2] 7. Application of design and optimization tools: Pro-Engineer / Catia and Altair Hyperworks, Matlab and MS Excel [1] 8. Advanced Topics in Optimization: a) approximation methods (response surfaces), b) material design, c) MEMS, d) topographical optimization, e) rapid prototyping [1] 		
Intended Learning outcomes: to demonstrate		
a knowledge and understanding of:	The principles, concepts and limitations of various methods for structural topology and shape optimisation. The mathematical principles behind gradient free and gradient based optimisation algorithms. The principles of differentiation of finite element based problems to obtain first order sensitivities. Necessary condition for optimum solutions. The interaction between objective and constraint functions.	
an ability to: (thinking skills)	Formulate general optimisation problems with objective function(s), constraint functions and side constraints on the design variables. Determine optimality conditions for general optimisation problems. Identify appropriate optimisation methods for a variety of problems. Distinguish between topology and shape optimisation and identify appropriate methods for solving these problems.	
an ability to: (practical skills)	Solve optimisation problems using Matlab (quasi-Newton BFGS or GA optimisers) or Excel (GrG optimiser). Apply the fully integrated design method to design 2D and 3D structures with minimal weight or compliance. Extract or interpret the results from topology optimisation for further use in shape optimisation. Determine the reinforcement pattern of structures. Design minimum weight or minimum compliance structures using a combination of commercial software (Matlab, Altair Hyperworks and ProE/Catia).	
an ability to: (key skills)	Use a personal computer. Study independently and use library resources. Effectively take notes and manage working time. Write technical reports. Use mathematical concepts for solving real problems. Use commercial software.	
<p>Assessment: 80 % course work of 20 pages maximum that is split into 4 parts (problem definition (15%), Matlab (25%), Excel (15%) and topology optimisation (25%)) and 20 % oral exam.</p> <p>Penalty for late submission: 1 mark per calendar days overdue.</p> <p>Penalty for overlong submission: 0.5 marks per page.</p>		
<p>Recommended texts: Principles of optimal design: modelling, computation, P.Y. Papalambros and D.J. Wilde, Cambridge University Press, ISBN 0-521-62727-3.</p> <p>Optimization concepts and applications in engineering, A.D. Belgundu, T.R. Chandruptla, Prentice Hall, ISBN 0-13-031279-7.</p> <p>Homogenization and structural topology optimization: theory, practice and software. B. Hassani and E. Hinton, Springer Verlag, ISBN 3-540-76211-6.</p> <p>Further reading: Software: Altair Hyperworks (www.altair.com), PTC Pro-Engineer and/or Catia (www.ptc.com or www.catia.com), Matlab and MS Excel Related Websites: NEOS (network-enabled optimization system): www.mcs.anl.gov/otc, Decision Tree for Optimization Software: plato.la.asu.edu/guide.html, TopOpt: www.topopt.dtu.dk, Mathematical Programming Glossary: carbon.cudenver.edu/~hgreenbe/glossary/glossary</p>		

COMPUTATIONAL INTELLIGENCE IN ENGINEERING		
Credits: 5 Term: 2 Compulsory: NO		
Format :	Lectures	18h
	Examples	32h
	Private study	75h
Lecturers: R.S. Ransing		
Contents:		
1. Introduction to Computational Intelligence: [1]		
2. Neural Networks: Perceptron learning, Single layer and multi-layered feedforward neural networks. Radial Basis functions, Competitive learning and Self organising Maps. Comparison with equivalent statistical techniques. [10]		
3. Supervised Learning in Neural Networks: Gradient descent methods, Conjugate Gradient Methods, Quasi-Newton Methods and Levenberg-Marquardt Method [4]		
4. Introduction to Fuzzy Sets and Genetic Algorithms: [3]		
Intended Learning outcomes: to demonstrate		
a knowledge and understanding of:	Computational intelligence methods such as neural networks, fuzzy sets and genetic algorithms.	
an ability to: (thinking skills)	Identify neural network methods used for data analysis application. Distinguish between statistical and neural network methods. Distinguish between Computational Intelligence methods and Artificial Intelligence methods. Identify appropriate optimisation methods for learning.	
an ability to: (practical skills)	Use neural network methods, fuzzy set and genetic algorithm methods for data mining applications.	
an ability to: (key skills)	Study independently, solve practical problems, develop computer programming and computer application skills and manage working time.	
Assessment: 80% continuous internal assessment (computer assignments/projects and a class test) + 20% oral examination		
Recommended texts: Neural Networks for Pattern Recognition by C.M. Bishop Oxford University Press, ISBN: 0-19-853864-2 NETLAB, Algorithms for Pattern Recognition by Ian T Nabney, Springer, ISBN 1-85233-440-1 Principles of Neurocomputing for Science and Engineering by Ham and Kostanic, McGraw Hill International Edition, ISBN 0-07-118161-X		

NANOSCALE SIMULATION		
Credits: 5 Term: 1 Compulsory: NO		
Format :	Lectures	12h
	Examples	33h
	Private study	80h
Lecturers: Prof P Rees		
Contents:		
<ul style="list-style-type: none"> • Quantum mechanics – Bohr model of the atom, Schrodinger equation, energy eigenvalues and wavefunctions of the hydrogen atom. • Application of quantum mechanics to nano-scale semiconductor structures – Semiconductor band structure, effective mass approximation, quantum wells, wires and dots, density of states for electrons, quantum devices. • Molecular modelling – Basic atomic forces and bonding, small molecule models, proteins, molecular modelling packages. • Transport of particles – Electron transport; diffusion and conduction, nano-fluidics, rate equations and Monte Carlo simulations. 		
Intended Learning outcomes: to demonstrate		
a knowledge and understanding of:	To demonstrate an understanding quantum mechanics To apply quantum mechanics to semiconductor materials and devices, to model simple molecules and to have an understanding of the kinetics of particles at the nanoscale	
an ability to: (thinking skills)	understand the physics which effect devices on the nanometer scale. Critically review research information sources.	
an ability to: (practical skills)	develop computer models to solve differential equations.	
an ability to: (key skills)	solve a wide range of mathematical problems numerically. Literature searches, written and oral presentational skills, numerical modelling.	
Assessment: 60% continuous assessment assignments exam, 40% from end of Term examination		
Recommended texts: <i>Quantum Mechanics</i> , R.L.Liboff, Addison Wesley 1998. <i>Molecular Modelling. Principles and Applications.</i> , A. R. Leach. Addison Wesley Longman, 1996		

2nd Term Modules

Ecole Centrale de Nantes

Compulsory modules	Total ECTS	Structural Eng. ECTS	Eng. Hydro-dynamics ECTS
eXtended Finite Element Method and Level Set techniques	3	3	
Multi-Scale Structural Analysis	3	3	
Materials Modelling for Numerical Simulations	4	4	
Fluid Mechanics	5		5
Numerical techniques for PDEs in fluids	5		5

Elective modules

Computational Damage and Fracture Mechanics for Composites and Polymers	5	5	
Durability of Concrete Structures	5	5	
Numerical and physical modelling strategies for viscous naval hydrodynamics	5		5
Computational methods for incompressible flows and applications to optimization and flow control	5		5

EXTENDED FINITE ELEMENT METHOD AND LEVEL SET TECHNIQUES		
Credits: 3 Semester: 2 Compulsory: YES		
Format :	Lectures	12.5h
	Examples	7.5h
	Private study	60h
Lecturers: N. MOËS and N. CHEVAUGEON		
Contents:		
<p>The course presents an extension of the finite element method baptised, X-FEM, which is currently widely used in research and starts to appear in Industry. This method basically eliminates the need to mesh physical surfaces (cracks, holes, material interfaces, ...) in finite element computations. The surfaces are located and evolved by the level set technique which is also taught in the course. The topics are organized as follows :</p> <ul style="list-style-type: none"> • Overview of a wide class of problems that cannot be solved efficiently by the finite element method and necessity to extend the method • The keystones of the extended Finite Element Method : enrichment with the partition of unity and level set representation of surfaces • Detailed approach to model surfaces of discontinuity in a field, a derivative of a field and in the matter for linear static problems • Industrial applications in fracture mechanics. • Level sets and fast marching algorithms to evolve surfaces • More advanced topics with X-FEM : Large deformation, Contact and Explicit Dynamics. 		
Intended Learning outcomes: to demonstrate		
A knowledge and understanding of:	the current difficulties encountered by the finite element method; the partition of unity to model surfaces for linear and nonlinear problems; the level set technique to evolve surfaces; basic knowledge of nonlinear finite elements for static and dynamics.	
an ability to: (thinking skills)	identify the need for extended finite elements and level sets in problems taken for different areas of mechanics.	
an ability to: (practical skills)	logically formulate a numerical approach using extended finite elements and level sets for different practical problems and translate the formulation to an existing extended finite element code	
an ability to: (key skills)	study independently; use library resources; use an existing extended finite element code; effectively take notes and manage working time.	
Assessment: 50% project work, 50% from end of semester examination (open book)		
Practical Work:		
<ul style="list-style-type: none"> • Exercises will be set, which will involve the use of an existing software. • Understand and explain a research paper on the topic. 		
Recommended texts: Lecture notes		
<i>A dozen recent research papers in english on X-FEM and level sets.</i>		
Further readings:		
Osher, S., Fedkiw, R., <i>Level set methods and dynamic implicit surfaces</i> , Springer, 2003.		

MULTI-SCALE STRUCTURAL ANALYSIS		
Credits: 3 Semester: 2 Compulsory: YES		
Format :	Lectures	12.5h
	Examples	7.5h
	Private study	60h
Lecturers: P. CARTRAUD		
Contents:		
<p>This course presents classical approaches and recent advances in multi-scale analysis for structural mechanics. These methods allow for an efficient modeling and computation of many modern engineering applications, where complex and highly heterogeneous microstructures are used. The topics include :</p> <ul style="list-style-type: none"> • Introduction : presentation of various engineering applications with multiple scales • Illustrative examples of beams and laminated plates • Sequential techniques : <ul style="list-style-type: none"> • Basic concepts • Classical approaches in micromechanics of materials • Homogenization of periodic media • Numerical implementation • Accuracy of the multi-scale solution • Embedded techniques : <ul style="list-style-type: none"> • FE² methods • Superposition of coarse and fine meshes • Use of domain decomposition method • Overview of other methods (two-scale FEM, GFEM, variational multi-scale method...) 		
Intended Learning outcomes: to demonstrate		
A knowledge and understanding of:	the limits encountered by 3D detailed models for finely heterogeneous structures; the fundamentals of multi-scale computational approaches; the different steps of sequential techniques; the basic elements of embedded techniques.	
an ability to: (thinking skills)	understand and formulate a multi-scale approach for problems taken from different engineering applications; be able to assess advantages, applicability and limitations of the methods used.	
an ability to: (practical skills)	logically formulate a numerical method using an existing finite element code, perform micro- and macro-scale computations.	
an ability to: (key skills)	study independently; use library resources; use an existing finite element code; effectively take notes and manage working time.	
Assessment: 50% technical report, 50% from end of semester examination open book) Practical Work: bibliography analysis and finite element tutorials.		
Recommended texts: Zohdi T.I., Wriggers P., <i>Introduction to Computational Micromechanics</i> , Springer, 2005 <i>Recent research papers.</i>		
Further readings: Böhm H.J., <i>A Short Introduction to Basic Aspects of Continuum Micromechanics</i> , Cdl-fmd report 3-1998, http://ilfb.tuwien.ac.at/links/downloads/cdlfmdrep03.pdf , TU Wien, Vienna.		

MATERIALS MODELING FOR NUMERICAL SIMULATIONS		
Credits: 4 Semester: 1 Compulsory: YES		
Format :	Lectures	15h
	Examples	15h
	Private study	70h
Lecturers: A. POITOU and S. LE CORRE		
Contents:		
<p>This course intends to give the basics of non linear materials modeling for both solids and non Newtonian fluids and to illustrate how these behaviors are accounted for in numerical computations</p> <ul style="list-style-type: none"> • Overview of basic behaviors in one dimension • Thermodynamics • Plasticity of metals, cyclic and isotropic hardening, for infinitesimal deformations. Viscoplasticity, high strain rates. • Viscoelasticity of fluids • Thermal coupling • Integration algorithm for plasticity • Numerical algorithm for advection problems • Case study <ul style="list-style-type: none"> • Abaqus • FeMlab 		
Intended Learning outcomes: to demonstrate		
A knowledge and understanding of:	Fundamentals of thermodynamics of materials and its consequences on materials modeling. Metal plasticity, internal variables, polymer viscoelasticity, induced anisotropy.	
an ability to: (thinking skills)	understand and formulate basic constitutive relations and implement them or simply call them in a Finite Element code.	
an ability to: (practical skills)	understand the physical meaning of most classical constitutive relations for metal plasticity and polymer viscoelasticity. Run and discuss practical case studies involving them.	
an ability to: (key skills)	Choose a constitutive relation in a library (Abaqus for example) and run it to for different case studies.	
<p>Assessment: 30% continuous assessment assignments, 70% from end of semester examination (50% open-book). Practical Work: Exercises will be set, which will involve using Abaqus and FeMlab.</p>		
<p>Recommended texts: Simo J.C. and Hughes T.J.R. , <i>Numerical Computational Inelasticity</i>, Springer, 1997 Lemaître J. and Chaboche J.L. , <i>Mechanics of solids materials</i>, Cambridge University Press,1995</p>		
<p>Further readings: Jean Lemaître <i>Handbook of materials behavior models</i> Lectures in Mathematics, Academic press 2001</p>		

FLUID MECHANICS		
Credits: 5 Semester: 2 Compulsory: YES		
Format :	Lectures	22.5h
	Examples	8.75h
	Private study	100h
Lecturers: Jean Piquet		
Contents:		
<p>This course presents basic knowledge in fluid mechanics related to the Navier-Stokes equations.</p> <ul style="list-style-type: none"> • Overview of the Navier-Stokes equations (compressible and incompressible flows). Far field behaviour. • Resolution of discontinuities within the Navier-Stokes equations • Boundary layers. • Other thin layers. • Identification of some flow characteristics. • The turbulent closure problem and levels of statistical treatment. Homogeneous flows. • Eddy-viscosity models and some of their algebraic extensions. • Reynolds-stress models. • Principles and overview of large-eddy simulations. 		
Intended Learning outcomes: to demonstrate		
A knowledge and understanding of:	the physical contents of Navier-Stokes equations, Oseen's and Boundary layer approximation, The principles of turbulent modeling, drawbacks and limitations	
an ability to: (thinking skills)	Select the models, the equations and their suitable boundary conditions	
an ability to: (practical skills)	Ability to formulate equation settings with adequate boundary conditions, both for mathematical and physical aspects.	
an ability to: (key skills)	study independently ; effectively take notes and manage working time ; select adequate levels of description.	
<p>Assessment: 50% continuous assessment assignments, 50% from end of semester examination (open-book). Practical Work: Exercises will be set.</p>		
<p>Recommended texts: Lecture notes Piquet, J., <i>Turbulent Flows, Models and Physics</i>, Springer, 1999 White, F. , <i>Viscous Flows</i> Further readings: Sagaut, P. <i>Large-eddy simulations</i>, Springer, 1998</p>		

NUMERICAL TECHNIQUES FOR PDE'S IN FLUIDS		
Credits: 6 Semester: 1 Compulsory: YES		
Format :	Lectures	22.5h
	Examples	8.75h
	Private study	100h
Lecturers: Jean PIQUET		
Contents:		
<p>This course presents some “tactical questions” for the numerical solution of partial differential equations. Topics are mainly related to finite volume techniques on structured and unstructured grids. Tactical questions involve the following aspects :</p> <ul style="list-style-type: none"> • Reconstructions of fluxes in finite-volume techniques. • Discretization of diffusion operators. • Acceleration of convergence of iterative solvers via multigrid and Krylov methods. • Grid generation using transfinite interpolation and PDE methods. • Surface-grid description. 		
Intended Learning outcomes: to demonstrate		
A knowledge and understanding of:	Required tactical aspects of the solution of partial differential equations (mainly in the context of Navier-Stokes equations)	
an ability to: (thinking skills)	formulate basic numerical procedures and solve illustrative problems.	
an ability to: (practical skills)	logically formulate numerical techniques for solution by computer with a programming language (Fortran).	
an ability to: (key skills)	study independently; use library resources; use a personal computer for basic programming; effectively take notes and manage working time.	
Assessment: 50% project work, 50% from end of semester examination (50% open-book). Practical Work: Exercises will be set, which will involve coding some of the presented methods.		
Recommended texts: Lecture notes of JP Leveque, R., <i>Numerical Methods for Conservation Laws</i> , Lectures in Mathematics, ETH Zürich, 1992 Thompson, J.J., Warsi, Z.U.A. & Mastin , <i>Numerical Grid generation</i> , Elsevier, 1982 Trefethen, L.N. & Bau, D., <i>Numerical linear algebra</i> , SIAM, 1996 Briggs, R. “ <i>Multigrid, a tutorial</i> ”, SIAM, 1989.		
Further readings: Osher, S. & Fedkiw, R. <i>Level set Methods and Dynamic implicit surfaces</i> , Springer, 2002. Saad, Y., <i>Iterative methods for sparse linear systems</i> . Academic Press, 2000. Shashkov, M. <i>Conservative Finite difference schemes on general grids</i> . CRC Press, Boca Raton, FL,1995.		

COMPUTATIONAL DAMAGE AND FRACTURE MECHANICS FOR POLYMERS AND COMPOSITES		
Credits: 5 Term: 2 Compulsory: NO		
Format :	Lectures	15h
	Examples	5h
	Private study	125h
Lecturers: L. GORNET, E. VERRON		
Contents:		
<p>This module presents the fundamentals of mechanical response, damage and fracture of polymers and composites as applied to design. The emphasize is laid on the continuum mechanics description and computational aspects.</p> <p>Topics:</p> <ul style="list-style-type: none"> • Overview of polymers and reinforced composites: basic chemistry and microstructure, mechanical response, testing methods, • Constitutive models for engineering applications: formulation and numerical implementation <ul style="list-style-type: none"> ○ composites: anisotropic linear elasticity, yield criteria, damage models, application to naval architecture, ○ polymers: large strain rubber-like elasticity and viscoelasticity, stress-softening, application to automotive rubber parts. • Fracture and fatigue: <ul style="list-style-type: none"> ○ Linear fracture mechanics: Griffith crack theory, stress intensity factors, J integral, ○ Specific numerical methods, ○ Extension to non-linear elasticity and inelasticity, ○ Fatigue life prediction. 		
Intended Learning outcomes: to demonstrate		
a knowledge and understanding of:	The basic elements of microstructure of polymers and composites; relevant constitutive models for engineering applications; basics of fracture theory; finite element implementation and numerical simulation of structural responses including fracture and fatigue life prediction.	
an ability to: (thinking skills)	Understand and formulate basic models and numerical simulations.	
an ability to: (practical skills)	Design non-metallic engineering structures and predict their mechanical response. Analyze and perform the corresponding computations.	
an ability to: (key skills)	Study independently, use library resources, use existing commercial finite element code.	
<p>Assessment: 50% continuous assessment assignments, 50% from end of Term examination (50% open-book).</p> <p>Practical Work: Exercises will be set, which will involve finite element tutorials.</p>		
<p>Recommended texts: Lecture notes Herakovich, C. T., <i>Mechanics of Fibrous Composites</i>, John Wiley & Sons, 1998. Holzapfel G., <i>Nonlinear Solid Mechanics. A continuum approach for engineering</i>, John Wiley & Sons, 2000.</p> <p>Further readings: Ward, I. M.; Sweeney, J., <i>Introduction to the Mechanical Properties of Solid Polymers, second edition</i>, John Wiley & Sons, 2004. Gdoutos E. E., <i>Fracture Mechanics. An introduction, second edition</i>, Springer, 2005.</p>		

DURABILITY OF CONCRETE STRUCTURES		
Credits: 5 Semester: 2 Compulsory: NO		
Format :	Lectures	20h
	Examples	15h
	Private study	90h
Lecturers: A. LOUKILI, G. PIJAUDIER-CABOT, F. DUFOUR		
Contents:		
<p>This course focuses on the various ageing mechanisms in cementitious materials and on the computational issues related to their simulations in durability mechanics applications. It covers:</p> <ul style="list-style-type: none"> • Fundamentals on chemistry and microstructure of cementitious materials • Hydration and early age deformation of concrete • Review of the various ageing mechanisms controlled by transfer properties • Poromechanics –hydromechanics and chemomechanics • Fracture properties of concrete structures and their interaction with ageing (hydro and chemo-mechanics coupling, creep-fracture interaction) • Computer methods for such coupled problems (staggered and coupled schemes) 		
<i>Intended Learning outcomes: to demonstrate</i>		
A knowledge and understanding of:	The basic elements of the microstructure of cementitious materials; the mechanisms behind creep, shrinkage and instantaneous response of concrete; interactions between damage and ageing phenomena	
an ability to: (thinking skills)	understand and formulate basic constitutive modeling for concrete including damage, creep, shrinkage, understanding of poromechanical models and formulate examples of coupled constitutive relations (e.g. damage – permeability); identify the proper numerical procedures.	
an ability to: (practical skills)	understand practical implications of ageing on the durability (life time) of concrete structure; analyse and carry out the corresponding simulations	
an ability to: (key skills)	study independently; use library resources; use a personal computer for basic programming; effectively take notes and manage working time.	
Assessment: 50% project work, 50% from end of semester examination. Practical Work: computer project		
Recommended texts: Concrete : Microstructure, properties and materials, P. Khumar Mehta and Paulo J.M. Monteiro, Mc Graw Hill, 2006. F. Darve and I. Vardoulakis (Eds.), <i>Degradation and Instabilities in Geomaterials</i> , CISM Lecture notes, Springer, 2004 Z.P. Bazant, J. Planas, <i>Fracture and size effect in concrete and other quasi-brittle materials</i> , CRC press, 1998 A. Neville, <i>Properties of concrete</i> , Eyrolles, 2000		
Further readings: M.Pastor a,d C. Tamagnini (Eds), <i>Numerical Modelling in Geomechanics</i> , special volume of Revue Française de Génie Civil,2002.		

NUMERICAL AND PHYSICAL MODELLING STRATEGIES FOR VISCOUS NAVAL HYDRODYNAMICS		
Credits: 5 Semester: 1 Compulsory: NO		
Format :	Lectures	25h
	Examples	25h
	Private study	75h
Lecturers: M. Visonneau and A. LEROYER		
Contents:		
<p>This course presents the modelling strategies which are used to compute viscous hydrodynamic flows by solving the Incompressible Reynolds-Averaged Navier-Stokes Equations. It covers :</p> <ul style="list-style-type: none"> • a brief overview of the main turbulence closures used in high Reynolds incompressible flows • a study of the coupling strategies to account for the incompressibility and various pressure-velocity coupling algorithms • a description of a general face-based unstructured Finite Volume discretisation • an overview of compressive discretisation schemes to use with free-surface capturing approach • a critical review of various applications ranging from free-surface flows around ships (model and full scale) with or without waves to impact flows 		
Intended Learning outcomes: to demonstrate		
A knowledge and understanding of:	the basic elements needed to build reliable numerical and physical modelling strategies to solve Reynolds Averaged Navier Stokes Equations for naval hydrodynamic applications.	
an ability to: (thinking skills)	understand the basic properties which must be fulfilled by the modelling strategies at continuous and discrete levels	
an ability to: (practical skills)	understand the limitations and requirements of discretisation methods needed to solve RANSE for high Reynolds flows around complex geometries with a focus on free-surface flows	
an ability to: (key skills)	study independently; use library resources; use a personal computer for basic programming; effectively take notes and manage working time.	
Assessment: 60% project, 40% from end of semester examination		
Practical Work: CFD projects will be proposed through the use of ISIS CFD code developed by the CFD research team.		
Recommended texts:		
M. Peric and J. Ferziger., <i>Computational methods for fluid dynamics</i> , Springer Verlag, 2002		
Further readings:		
Peyret R., <i>Handbook of Computational Fluid Mechanics</i> , Academic Press, 1996		

COMPUTATIONAL METHODS FOR INCOMPRESSIBLE FLOWS AND APPLICATIONS TO OPTIMIZATION AND FLOW CONTROL

Credits: 5 **Term:** 1 **Compulsory:** NO

Format :	Lectures	25h
	Examples	15h
	Private study	125h

Lecturers: M. VISONNEAU

Contents:

This module presents the modelling strategies which are used to compute viscous incompressible flows by solving the Reynolds-Averaged Navier-Stokes Equations. This module is particularly focussed on shape optimization and flow control in computational fluid dynamics characterized by high Reynolds number and complex geometries. It covers :

- a study of the coupling strategies to account for the incompressibility constraint
- a description of a general face-based unstructured Finite Volume discretisation
- an overview of several optimization strategies ranging from deterministic methods to genetic algorithms
- a review a various approaches used to reduce complexity (neuronal networks, POD,...)
- a study of several mesh deformation algorithms
- a critical review of various applications ranging from shape optimisation for ship hulls or wings and optimal flow control in aerodynamics

Intended Learning outcomes: to demonstrate

A knowledge and understanding of:	the basic elements needed to build a reliable numerical and physical modelling strategy used in an optimization or control loop by solving Reynolds Averaged Navier-Stokes Equations.
an ability to: (thinking skills)	understand the basic properties which must be fulfilled by the modelling strategies at continuous and discrete levels and the problems which result from the coupling of flow solver and optimization tools when complex configurations are addressed.
an ability to: (practical skills)	understand the limitations and requirements of discretisation methods and optimization/control algorithms needed to solve RANSE for high Reynolds flows around complex geometries.
an ability to: (key skills)	study independently; use library resources; use a personal computer for basic programming; effectively take notes and manage working time.

Assessment: 30% continuous assessment assignments, 70% from end of Term examination (50% open-book).

Practical Work: Small scale CFD projects will be proposed through the use of ISIS CFD code developed by the CFD research team.

Recommended texts: Lecture notes

P. E. Gill, W. Murray and M.H. Wright, *Practical Optimization*, Academic Press, 1986

Goldberg., *Genetic Algorithms in search, optimization and machine learning*, Addison Wesley, 1989

M. Gad El Hak, *Flow Control*, Cambridge University Press, 2000

2nd Term Modules

Universität Stuttgart

Elective modules	Total ECTS	Solid Mechanics ECTS	Eng. Materials ECTS
Advanced Computational Mechanics of Structures*	6	6	-
Boundary Elements Methods in Statics and Dynamics*	6	6	-
Engineering Materials: Metals [#]	2	-	2
Engineering Materials: Concrete [#]	3	-	3
Engineering Materials: Soils [#]	2	-	2
Foundations of Porous and Multiphase Continua	6	4	2
Micromechanics of Materials and Homogenization Methods	6	2	4
Software Development and Numerical Programming	6	3	3
Adaptive Systems	6	3	3
Theory and Numerics of Materials at Large Strains	6	2	4
Numerical Algorithms for ODE and Linear Systems	6	3	3

* Mandatory modules for the Solids and Structures minor.

[#] Mandatory modules for the Engineering Materials minor.

ADVANCED COMPUTATIONAL MECHANICS OF STRUCTURES		
Credits: 6 Term: 2 Compulsory: No		
Format :	Lectures	28h
	Examples	14h
	Private study	125h
Lecturer: E. RAMM		
Contents:		
The module consists of two parts:		
<ol style="list-style-type: none"> 1. The first part presents a <i>linear theory for arbitrary thin shells</i> and a corresponding finite element discretization is given. The module starts with an introduction in curvilinear coordinates, followed by linear continuum mechanics in a curvilinear setting. The concept of dimensional reduction applying kinematic and static assumptions leads to a general shell formulation including transverse shear deformation in the context of a Reissner-Mindlin kinematics. The related weak form yields the basis for a finite element discretization, exemplified for a three-node triangular element. 2. The second part is devoted towards <i>geometrically nonlinear analyses, in particular of thin-walled structures</i>. First, the general nonlinear responses are discussed, where notions of load and displacement control, bifurcation limit and turning points etc. are introduced. This is followed by a brief review of nonlinear continuum mechanics in the setting of a material formulation. The von Mises truss system is used to derive the nonlinear characteristic and serves as a benchmark for linearization and Newton-type solution schemes applying different controlling methods (load, displacement, arc-length control). Finally, the nonlinear formulation is described for a continuum and a two-dimensional finite element for arbitrarily large displacements is derived. 		
Intended Learning outcomes: to demonstrate		
a knowledge and understanding of:	the fundamentals for the analyses of arbitrary thin shells (dimensional reduction) and its finite element discretization; a first insight into large deformation problems, in particular for thin-walled structures.	
an ability to: (thinking skills)	understand the derivation of structural theories and their application in a nonlinear setting.	
an ability to: (practical skills)	model structural problems in practice and to understand the fundamental behavior of structures, in particular in a complex environment, like arbitrary curved structures or in the nonlinear range.	
an ability to: (key skills)	study with an own responsibility, use other textbooks, apply commercial software packages, and manage the own working time.	
Assessment: .		
4 continuing assignments are required. Midterm exam counting 35 %, final exam (65 %) at the end of the Term (second week after modules finish), open book.		
Recommended texts: The module is based on own lecture notes which are only partially filled out. It is a combination of beamer projection and black board presentation.		
<i>Books:</i> D.Talaszidis, G. Wempner: Mechanics of Solids and Shells, Theory and Approximations. CRC Press, 2003.		
T. Belytschko, W.K. Lin, B. Moran: Nonlinear Finite Elements for Continua and Structures. Wiley, 2000.		
Further readings:		
J.F. Doyle: Nonlinear Analysis of Thin-walled Structures. Springer, 2001.		

BOUNDARY ELEMENT METHODS IN STATICS AND DYNAMICS		
Credits: 6 Term: 2 Compulsory: No		
Format :	Lectures	30h
	Examples	10h
	Private study	125h
Lecturer: L. GAUL		
Contents:		
<p>The module covers the numerical solution of boundary value problems by boundary element methods (BEM). Boundary integral equations are derived from weighted residual techniques with fundamental solutions as weighting functions. The numerical implementation of BEM covers the discretization of geometry and boundary data, numerical integration of boundary integrals and field data evaluation.</p> <p>Application to problems in potential theory (heat conduction), acoustics and elastomechanics including structure borne sound propagation are presented. An outlook on advanced topics like fast Multipole BEM, hybrid BEM, Dual Reciprocity BEM and BEM-FEM mortar coupling is given.</p>		
Intended Learning outcomes: to demonstrate		
a knowledge and understanding of:	the fundamentals of boundary element methods and their numerical implementation; advantages, applicability and comparison to FEM.	
an ability to: (thinking skills)	understand and formulate basic BEM procedures and solve illustrative problems.	
an ability to: (practical skills)	implement basic techniques such as numerical integration and to develop a complete simple BEM-code in a step-by-step guided homework project with the programming language Matlab; understand commercial BE-programs.	
an ability to: (key skills)	study independently and in team; use a personal computer for solving BEM problems and do basic programming; project work; effectively take notes and manage working time.	
<p>Assessment: 100% from end of Term examination (closed-book). 50% of the homework problems and projects are mandatory for the admission to the examination.</p>		
Recommended texts:		
Lecture notes on the homepage of the online-module: www.bem.uni-stuttgart.de (Authors: Gaul, L., Fischer, M.)		
Gaul, L., Kögl, M., Wagner, M., <i>Boundary Element Methods for Engineers and Scientists</i> , Springer, 2003		
Further readings:		
Gaul, L., Fiedler, C., <i>Methode der Randelemente in Statik und Dynamik</i> , Vieweg, 1997		

ENGINEERING MATERIALS - CONCRETE		
Credits: 3 Term: 2 Compulsory: No		
Format :	Lectures	21 h
	Examples	0 h
	Private study	64 h
Lecturer: J. OŽBOLT		
Contents:		
<p>The development of computational models for detailed 3D finite element analysis of structures made of quasi-brittle materials is treated. Strong emphasis is placed on the application of these models to concrete and reinforced concrete structures. The topics of regularization techniques and adaptive remeshing are also discussed.</p> <ol style="list-style-type: none"> 1. Quasibrittle materials and motivation for non-linear analysis 2. Review of concrete behaviour in tension and compression 3. Modelling of concrete and basic thermodynamic principles 4. Fracture mechanics (LEFM, NLFM and size effect) 5. Plasticity based constitutive law for concrete 6. Damage based constitutive law 7. "The Smearred Crack Models" 8. Microplane theory 9. Objective modelling (regularization) and new developments 		
Intended Learning outcomes: to demonstrate		
a knowledge and understanding of:	The variety of methods currently used to numerically model concrete and reinforced concrete; the theoretical background for these methods; computational issues related to the detailed modelling of concrete and reinforced concrete	
an ability to: (thinking skills)	Express complex quasi-brittle material behaviour in a computational environment; understand the basic principles of the presented modelling frameworks	
an ability to: (practical skills)	Select an appropriate framework for a given application; identify and know how to avoid common pitfalls in the numerical modelling of quasibrittle materials	
an ability to: (key skills)	Study independently; synthesize diverse information; use a personal computer for basic programming; effectively take notes and manage working time	
Assessment: Optional biweekly homework assignments, 100% from end of Term examination.		
Recommended texts:		
Jirasek, M. & Bažant, Z. P.: <i>Inelastic Analysis of Structures</i> , J. Wiley and Sons, 2002		
Karihaloo, B. L.: <i>Fracture Mechanics & Structural Concrete</i> , Longman Scientific & Technical, 1995		
Further readings:		
Mazars, J. & Pijaudier-Cabot, G.: "Continuum Damage Theory – Application to Concrete"; <i>Journal of Engineering Mechanics</i> ; Vol. 115; No. 2; 1989; 345-365		
Ožbolt, J., Li, Y. & Kožar, I.: "Microplane Model for Concrete with Relaxed Kinematic Constraint"; <i>International Journal of Solids and Structures</i> , Vol. 38, 2001, pp. 2683-2711		
Rots, J. G.: <i>Crack Models for Concrete: Discrete or Smearred? Fixed, Multi-Directional or Rotating?</i> ; <i>Heron</i> ; Vol. 34, No. 1; 1989; 56 pgs.		

ENGINEERING MATERIALS – METALS		
Credits: 2 Term: 2 Compulsory: No		
Format :	Lectures	10h
	Examples	5h
	Private study	45h
Lecturer: Siegfried Schmauder		
Contents:		
<p>The aim of this module is to provide the student with a working knowledge for the modeling of metallic materials typically encountered in engineering design and analysis. This module focuses on understanding and predicting the mechanical behaviour of metals including static, dynamic and creep loading for a variety of problems in science and engineering. Emphasis will be placed on plasticity-based approaches for numerical analyses, strength calculations for static loading conditions as well as for cyclic loading, the mechanical behavior of materials including creep, the influences of notches and on the impact of damage and fracture in metals. Examples and tasks will be given for each of the topics.</p> <ol style="list-style-type: none"> 1. Mechanical Behavior of Metals 2. Notches, Creep 3. Damage and Fracture 		
Intended Learning outcomes: to demonstrate		
a knowledge and understanding of:	the fundamentals of the mechanical behaviour of metallic materials including deformation and fracture; models to solve problems in the field of simulating material behaviour.	
an ability to: (thinking skills)	understand and formulate basic tasks of the mechanical behavior of metals; solve illustrative problems and identify proper methods for their solutions.	
an ability to: (practical skills)	understand practical implications of analytical means, methods and solutions; logically formulate problems and evaluate practically relevant experimental and numerical results for metals.	
an ability to: (key skills)	study independently; use library resources; apply analytical and numerical tools as well to perform strength calculations; effectively take notes and manage working time.	
Assessment: No continuous assessment assignments; end of Term examination (100%). Practical Work: Exercises will be set, which will involve coding of the presented methods.		
Recommended texts: Lecture notes Smallman, R.E., Bishop, R.J., Metals and Materials, Science, Processes, Applications, Butterworth-Heinemann Ltd., Oxford, 1995		
Further readings: Raabe, D., Computational Materials Science, Wiley-VHC, Weinheim, 1998		

ENGINEERING MATERIALS - SOILS		
Credits: 2 Term: 2 Compulsory: No		
Format :	Lectures	14h
	Examples	4h
	Private study	40h
Lecturer: P.A. VERMEER		
Contents:		
<p>This module focuses on applications of rate independent elastoplastic constitutive models to simulate material responses of cohesive-frictional soils. The responses such as stress-strain relation and contraction-dilation behaviour before perfectly plastic state (Mohr-Coulomb failure boundary), are modelled based on 2 hardening laws: shear or frictional hardening and density or cap hardening. In the models, the use of non-associated flow rule originated from the concept of stress dilatancy is shown to be essential. An overview about some special topics such as viscous effects in soft soils and small strain stiffness is given also in this module.</p>		
<ol style="list-style-type: none"> 1. Density Hardening Model for loose Soils. <ol style="list-style-type: none"> a. Undrained soil testing with special reference to NC-clays and sands. b. Formulation of elastoplastic density hardening model c. Evaluation of the model. 2. Friction Hardening Model for Dense Soils. <ol style="list-style-type: none"> a. Stress-strain curves from triaxial tests. b. Hyperbolic approximation. c. Shear-strain contours. d. Flow rule and plastic potential. e. Final elastoplastic model. 3. Double Hardening Model. <p>Combination of friction and density hardening models.</p> 		
Intended Learning outcomes: to demonstrate		
a knowledge and understanding of:	Advantages and limitations of each soil models, as well as the selection of suitable input parameters from laboratory tests.	
an ability to: (thinking skills)	understand the soil mechanical behaviour (clays and sands) and identify the proper constitutive model for the corresponding soil.	
an ability to: (practical skills)	understand practical implications of soils behaviour and simulate it using a suitable advanced constitutive models.	
an ability to: (key skills)	study independently; use library resources effectively take notes and manage working time.	
<p>Assessment: 100% from end of Term examination (closed-book). Practical Work: Exercises will be set, which will involve deriving some constitutive equations and soil behaviour prediction under specific stress paths.</p>		
<p>Recommended texts: Lecture notes Biarez, J. & Hicher, P., <i>Elementary Mechanics of Soil Behaviour</i>, Balkema-Publishers, 1994 Wood, D.M., <i>Soil Behaviour and Critical State Soil Mechanics</i>, Cambridge University Press, 1990</p>		
<p>Further readings: Brinkgreve, R & Vermeer, P. A. <i>Plaxis Version 7</i>, Balkema-Publishers, 1998</p>		

FOUNDATIONS OF POROUS AND MULTIPHASE CONTINUA		
Credits: 6 Term: 2 Compulsory: No		
Format :	Lectures	28 h
	Examples	18 h
	Private study	120 h
Lecturer: W. Ehlers		
Contents:		
<p>The major objective of this elective module is to discuss the thermodynamical principles of continuum mechanics in order to provide an admissible constitutive framework for the theory of materials. Therefore, the content is split into three main parts: Thermodynamics, introduction to materials theory and fluid-saturated porous solid materials.</p> <p>Thermodynamics</p> <ol style="list-style-type: none"> 1. Thermodynamic Balance Laws <ol style="list-style-type: none"> a) Balance of energy (first law of thermodynamics) b) Entropy inequality (second law of thermodynamics) c) Thermodynamical potentials d) Application: 3-d thermoelasticity at finite strains <p>Introduction to Materials Theory</p> <ol style="list-style-type: none"> 1. Geometrically Linear Thermoelasticity <ol style="list-style-type: none"> a) Linearization of the finite problem b) Inversion of the linear law of thermoelasticity c) Determination of material parameters 2. Geometrically Linear Viscoelasticity <ol style="list-style-type: none"> a) Motivation and basic model rheology b) The standard model of viscoelasticity c) Clausius-Planck inequality and internal dissipation d) The 3-d viscoelastic solid 3. Geometrically Linear Elastoplasticity <ol style="list-style-type: none"> a) Motivation and basic model rheology b) Metal plasticity c) Generalised geomaterials plasticity <p>Fluid-Saturated Porous Solid Materials</p> <ol style="list-style-type: none"> a) Basic concepts b) Mechanical balance relations c) Constitutive equations <p>Darcy's filter law</p>		
Intended Learning outcomes: to demonstrate		
a knowledge and understanding of:	fundamentals of continuum thermodynamics with application to thermoelasticity, viscoelasticity and elastoplasticity; fundamentals of the Theory of Porous Media.	
an ability to: (thinking skills)	understand the physical and mechanical coherences in the modelling of engineering problems.	
an ability to: (practical skills)	develop an admissible continuum mechanical model (primary variables, balance equations, constitutive equations) describing the behaviour of materials.	
an ability to: (key skills)	study independently; use library resources; effectively take notes and manage working time.	
Assessment: 3 homework assignments, 100% from end of Term examination (100% open book).		
Recommended texts: Lecture notes Haupt, P., Continuum Mechanics and Theory of Materials, Springer-Verlag, Berlin 2000 Holzapfel, G. H., Nonlinear Solid Mechanics, John-Wiley & Sons, Chichester 2000		

MICROMECHANICS OF MATERIALS AND HOMOGENIZATION METHODS		
Credits: 6 Term: 2 Compulsory: No		
Format :	Lectures	28 h
	Examples	18 h
	Private study	120 h
Lecturer: C. MIEHE		
Contents:		
<p>The module covers basic concepts of the theoretical formulation and numerical implementation of elastic and inelastic material response at small strains. It introduces generic classes of material models for elasticity, viscoelasticity, plasticity, viscoplasticity and damage mechanics based on the exploitation of fundamental axioms of continuum-thermodynamics. Parallel to the theoretical set up, details of appropriate numerical solution algorithms for finite element implementations are taught in an integrated manner related to the specific material models. A focus is put on a differentiation between purely phenomenological and micromechanically-based constitutive models. This includes discussions of microstructures of elastically and plastically deforming metallic crystals, polymers and granular materials. These scenarios are put into the general context of a multiscale picture of materials. To this end the module introduces foundations of homogenization methods and micro-to-macro transitions.</p> <ol style="list-style-type: none"> 1. Foundations of continuum thermodynamics at small strains: kinematics, balance principles, dissipation postulates. 2. Theory and numerics of generic classes of material response: elasticity, viscoelasticity, plasticity, viscoplasticity and damage mechanics. 3. Micromechanically-based constitutive models for metallic crystals and polymers. 4. Multiscale modelling of materials and computational homogenization methods. 		
Intended Learning outcomes: to demonstrate		
A knowledge and understanding of:	Theoretical and computational foundations of constitutive modelling for basic phenomenological classes of materials, micromechanically-based models and multiscale characteristics of materials	
an ability to: (thinking skills)	Understand the different material responses and numerical implementation in the context of Finite Element Method on different length scales.	
an ability to: (practical skills)	Write their own material routines in connection with existing Finite Element codes for a variety of material responses using a programming language (C or Fortran 77)	
an ability to: (key skills)	Study independently; synthesize diverse informations; use a personal computer for basic programming; work with commercial Finite Element Codes including the implementation of new material routines;	
Assessment: 3 homework assignments, 100% from end of Term examination (30% closed book).		
<p>Recommended texts: Maugin, G.A., <i>The Thermomechanics of Plasticity and Fracture</i>, Cambridge, 1992 Lemaitre, J.& Chaboche, J.-L., <i>Mechanics of Solid Materials</i>, Cambridge, 1990 Simo, J.C. & Hughes, T.J.R., <i>Computational Inelasticity</i>, Springer, 1998</p> <p>Further readings: C. Miehe [2002], "Strain-Driven Homogenization of Inelastic Microstructures and Composites Based on an Incremental Variational Formulation", <i>International Journal for Numerical Methods in Engineering</i> 55 Issue 11 (2002), pp. 1285-1322. C. Miehe & A. Koch [2002], "Computational Micro-to-Macro Transitions of Discretized Micro-Structures Undergoing Small-Strain Deformations", <i>Archive of Applied Mechanics</i> 72 (2002), pp.300-317.</p>		

SOFTWARE DEVELOPMENT AND NUMERICAL PROGRAMMING		
Credits: 6 Term: 1 Compulsory: No		
Format :	Lectures	25h
	Examples	15h
	Private study	125h
Lecturer: H.-J. BUNGARTZ		
Contents:		
<p>This module presents advanced numerical methods and preprocessing aspects like grid generation. Software development is discussed based on numerical algorithms and their implementation using the programming language C/C++. The module also covers parallel programming and applications for High Performance Computing.</p> <ol style="list-style-type: none"> 1. Iterative solution of large systems of linear equations (conjugate gradients, the multigrid idea) 2. Standard methods for ordinary differential equations (single-step and multistep methods, explicit and implicit methods, stiffness), Application: Molecular dynamics 3. Basic discretization schemes for partial differential equations (finite differences vs. finite elements) 4. Grid generation (structured grids, unstructured grids, varying geometries) 5. Introduction to parallel programming (parallel architectures, topologies, granularity, performance evaluation); parallel algorithms; programming message-coupled systems; the MPI standard and practical working with MPI. 		
Intended Learning outcomes: to demonstrate		
a knowledge and understanding of:	Numerical methods and grid generation; Parallel computing	
an ability to: (thinking skills)	Application of numerical methods and computational geometry algorithms; Software development for numerical programs	
an ability to: (practical skills)	Programming in C/C++; Parallel programming (MPI)	
an ability to: (key skills)	use a computer for programming and solving problems; study independently; use library resources; effectively take notes and manage working time.	
Assessment: 100% from end of Term examination.		
Practical Work: Exercises will be set, which will involve coding some of the presented methods.		
Recommended texts: Lecture notes		
J. Stoer, R. Bulirsch: <i>Introduction to Numerical Analysis</i> , Springer, 1996		
B. Kernighan, D. Ritchie: <i>The C Programming Language</i> , ANSI C Version, Prentice Hall, 1988		
B. Stroustrup: <i>The C++ Programming Language</i> , Addison-Wesley, 1997		
MPI standard		
Further readings:		
A. Quarteroni, R. Sacco, F. Saleri: <i>Numerical mathematics</i> , Springer, 2000		
M. de Berg, M. van Kreveld, M. Overmars, O. Schwarzkopf: <i>Computational Geometry: Algorithms and Applications</i> , Springer, 2000		
W. Press: <i>Numerical Recipes</i> , Cambridge University Press, 2002		

ADAPTIVE SYSTEMS		
Credits: 6 Term: 2 Compulsory: No		
Format :	Lectures	25h
	Examples	15h
	Private study	110h
Lecturer: B. KRÖPLIN		
Contents:		
<p>After a short introduction in the control theory including system representation in the time and frequency domain as well as basic control concepts for single-input/single-output systems, the build up of a complete adaptive system is considered. The control theory is then extended to the control of multiple-input/multiple-output systems and the application of state-space based design methods. In practical exercises an introduction to system identification methods and structural control will be given. Furthermore the problem of fatigue will be considered with a special focus on adaptive materials. Finally, typical examples of adaptive systems (adaptive wing, adaptive rotorblade, structural-acoustic control) will be shown.</p>		
Intended Learning outcomes: to demonstrate		
a knowledge and understanding of:	Complete adaptive systems; fatigue problems of adaptive materials	
an ability to: (thinking skills)	Understand the problems and criteria of systems' analysis	
an ability to: (practical skills)	Analyze adaptive and improve systems	
an ability to: (key skills)	study independently; use library resources effectively take notes and manage working time.	
Assessment: 2 homework assignments, 100% from end of Term examination (closed-book). Practical Work:		
Recommended texts: Lecture notes D. J. Jendritza et al.: Technischer Einsatz neuer Aktoren, expert verlag, Renningen, 1995 T. Ikeda: Fundamentals of Piezoelectricity, Oxford University Press, 1990 IEEE Standards on Piezoelectricity J. Argyris, H.-P. Mlejnek: Texts on Computational Mechanics: Dynamics of Structures, Elsevier Science Publishers, 1991, A. Preumont: Vibration control of active structures, Kluwer Academic Publishers, Dordrecht, 1997		

THEORY AND NUMERICS OF MATERIALS AT LARGE STRAINS		
Credits: 6 Term: 2 Compulsory: No		
Format :	Lectures	28 h
	Examples	18 h
	Private study	120 h
Lecturer: C. MIEHE		
Contents:		
<p>The module gives an introduction to the theoretical foundations and algorithmic implementation of material models in the geometrically nonlinear context of finite strains. It first summarizes the kinematics of finite deformations with an accent on terminologies of modern differential geometry. Next, emphasis is put on the variational structure of finite elasticity. This includes basic discussions such as material objectivity and symmetry as well as weak convexity properties of stress potentials. These formulations are then extended to dissipative structures of materials such as finite viscoelasticity and finite plasticity. This includes particular representations of specific kinematic assumptions suitable for isotropic and anisotropic overall response. The module addresses advanced algorithmic formulations for the specific finite-strain models. This includes advanced stress update algorithms and consistent linearization techniques.</p> <ol style="list-style-type: none"> 1. Foundations of continuum thermodynamics at finite strains: kinematics, balance principles, dissipation postulates. 2. Variational formulation of finite elasticity: objectivity, symmetry, polyconvexity. 3. Models of finite strain viscoelasticity: multiplicative and additive approaches, stress update algorithms, consistent linearization techniques. 4. Models of finite plasticity: multiplicative and additive approaches, stress update algorithms, consistent linearization techniques. 5. Stability of materials and postcritical response: accompanying localization analyses and regularization techniques. 		
Intended Learning outcomes: to demonstrate		
a knowledge and understanding of:	Advanced theoretical and computational formulations for basic phenomenological material classes at finite strains, micromechanically-based models and multiscale characteristics of materials	
an ability to: (thinking skills)	Understand the different material responses and numerical implementation in the context of Finite Element Method on different length scales.	
an ability to: (practical skills)	Write their own material routines in connection with existing Finite Element codes for a variety of material responses using a programming language (C or Fortran 77)	
an ability to: (key skills)	Study independently; synthesize diverse information; use a personal computer for basic programming; work with commercial Finite Element Codes including the implementation of new material routines;	
Assessment: 3 homework assignments, 100% from end of Term examination (closed book)		
<p>Recommended texts: Marsden, J.E. & Hughes, T.J.R., <i>Mathematical Foundation of Elasticity</i>, Prentice-Hall, 1983 Belytschko, T. & Liu, W.K. & Moran, B., <i>Nonlinear Finite Elements for Continua and Structures</i>, Wiley, 2000</p> <p>Further readings C. Miehe [1996], "Numerical Computation of Algorithmic (Consistent) Tangent Moduli in Large-Strain Computational Inelasticity", <i>Computer Methods in Applied Mechanics and Engineering</i>, 134 (1996), pp. 223-240. C. Miehe [1998], "A Formulation of Finite Elastoplasticity Based on Dual Co- and Contra-Variant Eigenvector Triads Normalized with Respect to a Plastic Metric", <i>Computer Methods in Applied Mechanics and Engineering</i>, 159 (1998), pp. 223-260. C. Miehe, N. Apel & M. Lambrecht [2002], "Anisotropic Additive Plasticity in the Logarithmic Strain Space. Modular Kinematic Formulation and Implementation based on Incremental Minimization Principles for Standard Materials", <i>Computer Methods in Applied Mechanics and Engineering</i> 191 (2002), pp. 5383-5425. C. Miehe [2003], "Computational micro-to-macro transitions for discretized micro-structures of heterogeneous materials at finite strains based on the minimization of averaged incremental energy", <i>Computer Methods in Applied Mechanics and Engineering</i> 192 (2003), pp. 559-591.</p>		

NUMERICAL ALGORITHMS FOR ODES AND LINEAR SYSTEMS		
Credits: 6 Term: 2 Compulsory: No		
Format :	Lectures	25h
	Tutorials	15h
	Private study	125h
Lecturer: B. WOHLMUTH		
Contents:		
<p>In the first part of the lecture, algorithms for the numerical approximation of ordinary differential equations are thoroughly discussed. Fast solution methods for large systems of linear equations are subject of the second part.</p> <p>The lecture concentrates on the introduction of the required mathematical theory and on the development of the numerical algorithms. In the tutorial, special emphasis is placed on the implementation of the developed schemes within the Matlab programming environment.</p> <p>Overview of the module contents:</p> <ul style="list-style-type: none"> 12 Ordinary Differential Equations <ul style="list-style-type: none"> a. One-step methods b. Runge-Kutta methods c. Consistency, stability and convergence d. Multistep methods e. Solving stiff ODE systems 12 Iterative solvers <ul style="list-style-type: none"> a. Linear iterative solvers b. Krylov subspace methods for symmetric and unsymmetric systems 		
Intended Learning outcomes: to demonstrate		
a knowledge and understanding of:	the fundamentals of the behavior and numerical approximation of ordinary differential equations, including consistency, stability and convergence; iterative solution of linear systems of equations.	
an ability to: (thinking skills)	understand and formulate basic numerical procedures and solve illustrative problems; identify the proper methods for the corresponding ODE.	
an ability to: (practical skills)	understand practical implications of behavior of numerical methods and solutions; logically formulate numerical methods for solution by computer with a programming language (Matlab).	
an ability to: (key skills)	study independently; use library resources; use a personal computer for basic programming; effectively take notes and manage working time.	
<p>Assessment: 30% from three written assignments (including practical coding and theoretical exercises), 70% from end of Term examination (100% closed-book).</p> <p>Practical Work: Exercises will be set, which will involve coding some of the presented methods.</p>		
<p>Recommended texts: Lecture notes</p> <p>E.Hairer, S.Norsett, G.Wanner, <i>Solving Ordinary Differential Equations I</i>, Springer 1993</p> <p>E.Hairer, G.Wanner, <i>Solving Ordinary Differential Equations II</i>, Springer 1996</p> <p>A.Quarteroni, R.Sacco, F.Saleri, <i>Numerical Mathematics</i>, Springer 2000</p> <p>J.Stoer, R.Bulirsch, <i>Introduction to Numerical Analysis</i>, Springer 1992</p>		